# Comparative Analysis of Durability and Failure Rates in Feldspathic, Lithium Disilicate, and Alumina Veneers - Long-term Results

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**Abstract**

AIM: The objective of this study is to compare the durability and failure rates of feldspathic, lithium disilicate, and alumina veneers following treatment.
METHODS: A comprehensive search of the dental literature was conducted via the Pubmed database. From the selected studies, survival rates of feldspathic, lithium disilicate, and alumina veneers were extracted, along with failure rates of fracture, chipping, debonding, marginal adaptation, discoloration, staining, and secondary caries.
RESULTS: The average observation period was 10 years. The estimated survival rates were 95.3% for feldspathic, 95% for lithium disilicate, and 93% for alumina. The analysis of failure rates revealed the following: fractures occurred at rates ranging from 0.9% over 3.4 years to 5% after 11 years for feldspathic veneers. Lithium disilicate showed an average fracture rate of 3.6% over 9.8 years, whereas alumina had a 6.6% fracture rate over the same period. Chipping was higher for alumina veneers (16.5%) compared to feldspathic (4%) and lithium disilicate (3.6%). All three types of veneers experienced low debonding rates (1-2%). Marginal adaptation issues were more prevalent in alumina and feldspathic veneers than in lithium disilicate. Marginal discoloration was higher in alumina veneers compared to other types. Staining and secondary caries were observed at low average percentages across all veneer types.
CONCLUSION: Feldspathic, lithium disilicate, and alumina veneers exhibit high survival rates and durability. The most frequent failures are fractures, chipping, and marginal discoloration, while debonding, staining, and secondary caries are rare complications.

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# 1 Introduction

In recent times, dental aesthetics have become increasingly popular. The population, regardless of age and gender, pays more attention to facial appearance, and a beautiful smile showcasing aligned and white teeth is an essential part of this. Veneers are a minimally invasive aesthetic treatment solution for patients suffering from aesthetic non-conformities, such as tetracycline staining, malformations, malpositions, coronal fractures, diastemas, or severe discolorations (Alothman & Bamasoud, 2018). This aesthetic treatment is advantageous because it avoids tooth weakening through minimal preparations and ensures long-term clinical success (Linhares et al., 2018).

To perform veneer treatment, numerous techniques and various materials are available for restoring anterior teeth. The acceptance of veneers in anterior teeth is due to their excellent results (Alenezi et al., 2021). The success of all clinical procedures relies on proper indication, planning, protocol adherence, patient selection (for example, age, bruxism, occlusion, and others), and material selection. Nevertheless, studies have indicated that longevity can also be related to other factors such as adhesion to dentine (Rinke et al., 2020).

Over the years, technology and dentistry have evolved remarkably; adhesion has transformed contemporary dentistry, and dental ceramics have advanced their properties as well. Additionally, the use of ceramic veneers has escalated due to their exceptional aesthetic properties, enhanced strength, and resistance characteristics. Consequently, the success rate of veneers has increased, representing a reliable procedure (Morimoto et al., 2016). Many studies have investigated the longevity of ceramic veneers from months up to twenty years, and other authors have emphasized their investigations on the failure rates of specific ceramic materials (Alothman & Bamasoud, 2018).

However, information on clinical behaviour and situations that may cause failures when comparing alumina, feldspathic, and lithium disilicate over the years is lacking. It is challenging to determine which failures occur in each material and when. Few studies analyze these materials together. Gaining a better understanding would assist in determining the optimal material for specific cases and allow for the association of specific failures with factors that could have led to these failures (Morimoto et al., 2016).

The aim of this systematic review and subsequent meta-analysis is to compare three types of veneer materials: feldspathic, lithium disilicate, and alumina veneers. Following this comparison, the evaluation will focus on the durability and performance of the materials, considering several details.

First, it is essential to understand the characteristics of the three materials and identify which techniques and protocols are most appropriate in each case. Next, the study will establish survival rates and compare these concerning reasons for failure. Moreover, the investigation will focus on fracture, chipping, and debonding rates over the years. Additionally, it is vital to describe the degree of failures in marginal adaptation and compare which material is more susceptible to discoloration or staining. Lastly, it is crucial to assess the evidence of secondary caries in patients treated with veneers.

Furthermore, the evaluation of the performance, outcomes, and durability of these three materials over the years aims to guide better clinical decisions when designing a smile for patients. This will clarify which clinical and technical parameters may influence failures in each material and assist in recommending one material over another in clinical practice.

## 2 Methods

A comprehensive search of dental literature was conducted using the PUBMED database with the following keywords: (laminate veneer) AND (glass-ceramic), yielding 30 articles. Additionally, the search terms (veneer) AND (alumina) AND (survival) returned 81 articles. The terms (veneer) AND (feldspathic) AND (survival) resulted in the identification of 50 studies, while (veneer) AND (lithium disilicate) AND (survival) produced 36 articles. Moreover, a manual examination of the bibliographies of the selected articles uncovered an additional 2 articles, culminating in an initial total of 199 studies.

The investigation encompassed randomised trials, controlled trials, case series, and cohort studies, primarily in English. Following this comprehensive search, articles deemed relevant and specific were selected. Articles discussing occlusal veneers and composite veneers were excluded. The eligibility criteria included studies on ceramic veneers with a minimum follow-up period of 6 months, published within the last 25 years. Consequently, from all searches, 16 articles were deemed usable and selected for further analysis (**Figure 1**).

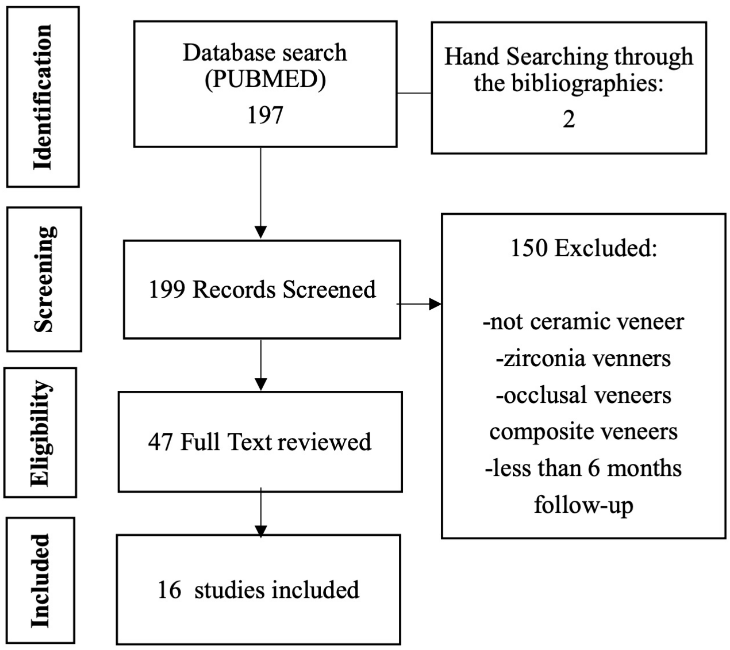


**Figure 1.** Flowchart of the study search and selection process.

For data analysis and the calculation of the average percentages of failures, including fracture, chipping, debonding, marginal adaptation, discolouration, and secondary caries, sample sizes were considered. This approach was adopted due to the varying numbers of veneers assessed in each study, impacting the final calculation.

The actual number of failures relative to the sample size of each study was calculated. Subsequently, the total number of failures and the total sample size were aggregated. The average percentage for each failure type was then determined by dividing the total number of failures by the total sample size.

To ensure a consistent evaluation, values deviating significantly from the ten-year follow-up were excluded from the calculation. Furthermore, failure rates markedly higher due to fluorosis or bruxism were also omitted.

## 2.1 Statistics

Descriptive statistics, frequency analysis, and content analysis were employed as part of the qualitative methodology to systematically analyze the textual content of the included studies. It is important to note that, given the narrative nature of this study, regression analysis and meta-analysis techniques were not deemed suitable for the analytical framework.

# 3 Results

Ceramic veneers are an effective solution for the correction of abnormalities in the anterior teeth. There are numerous types of ceramic veneers. This study compared three types: feldspathic, lithium disilicate, and alumina veneers. After extensive research on relevant articles, valuable information about their durability was obtained. Through the analysis of the collected data, it is important to describe the following aspects.

## 3.1 Study characteristics

Sixteen articles were finally included into the study (**Figure 1**). In this articles three main evaluation methods were used: The Modified United States Public Health Service (USPHS) Criteria, the Modified California Dental Association/Ryge Criteria and the World Dental Federation (FDI) Criteria. Due to the variety of parameters within these methods, one author decided to simplify them and classified failure as either "critical" or "non-critical", meaning critical if the restoration must be replaced and non-critical if the restoration can be repaired.

In all studies, there were more female patients than male patients (407 versus 257 males). The majority of studies were conducted on patients between 20-60 years, with a mean age of 40 years (**Table 1**). Approximately 53% of the studies included ages ranging from 19-66 years, and some also included teenagers (Dumfahrt & Schäffer, 2000). Additionally, 56.3% evaluated ceramic materials with a follow-up of at least 10 years. In 38.4% of the studies follow-up was done after 2, 3.4, 5, and 7 years.

## 3.2 General characteristics of materials for anterior restorations

The indications for dental veneers include discoloured teeth (due to various reasons such as tetracycline staining, amelogenesis imperfecta, fluorosis, and age); restoration of fractured teeth; correction of teeth morphology, and minor malpositions (Alothman & Bamasoud, 2018). Ceramic veneers differ in their characteristics, advantages, and disadvantages.

One of the most common veneer materials in dentistry is feldspathic ceramic. The main component of this material is feldspar, a naturally occurring glass that contains silicon oxide, aluminium oxide, potassium oxide, and sodium oxide (Layton & Walton, 2012b). This material is very thin, making it almost translucent, which provides aesthetic and natural results. Additionally, it requires only minimal tooth preparation, which can preserve enamel structure (Alothman & Bamasoud, 2018). One advantage of this material is that it can be etched with hydrofluoric acid, which provides excellent bonding strength to the enamel (Layton & Walton, 2012b) and has a high flexural strength of $350 \pm 450$ MPa (Cardoso & Dercurio, 2015).

However, some aspects must be considered: feldspathic veneers are not able to cover heavily discoloured teeth, and due to inner surface etching, micro-cracks may occur, causing biflexural strength to decrease and eventually fracture (Alothman & Bamasoud, 2018).

**Table 1.** Baseline characteristics of included studies. [LiDi] = Lithium disilicate; [PLV] = Porcelain Laminate Veneers; [Feld] = Feldspathic; [age] = years; [USPHS] = United States Public Health Service Criteria; [Ryge] = Modified California Dental Association/Ryge Criteria; [FDI] = World Dental Federation Criteria; [HT] = Human teeth; [St] = Student; [D] = Dentists; [NM] = Not mentioned.

| AUTHOR (YEAR) | VENEER TYPE | F-UP | EVAL. CRITERIA | AGE RANGE | VENEERS | PATIENTS | WOMEN | MEN | OPERATOR |
|---|---|---|---|---|---|---|---|---|---|
| **Alnakib (2021)** | LiDi | 0 | - | - | 24 | HT | 0,0 | 0,0 | St |
| **Arif (2019)** | PLV | 7-14 | Ryge | 40.0-60.0 | 114 | 26 | 19 | 7 | St |
| **Aslan (2019)** | LiDi | 10 | USPHS | 20.0-60.0, m 29.8 | 364 | 41 | 27 | 14 | D |
| **Attia (2021)** | PLV | - | USPHS | 20.0-30.0 | 54 | 6 | 4 | 2 | NM |
| **Beier (2012)** | LiDi | 10 | Ryge | 30.0-60.0 | 318 | 84 | 46 | 38 | D |
| **Demerekin (2022)** | LiDi | 10 | USPHS | 19.0-60.0 m: 49.7 | 358 | 34 | 20 | 14 | St |
| **Dumfahrt (2000)** | Feld | 10 | Ryge | 13.0-63.0 | 191 | 72 | 43 | 29 | D |
| **Fradeani (2005)** | Feld | 6 | Ryge | 20.0-66.0 | 182 | 46 | 29 | 17 | D |
| **Galindo (2011)** | Alu | 10 | USPHS | 27.0-60.0 | 112 | 29 | 19 | 10 | St |
| **Gresnigt (2019)** | Feld | 11 | USPHS | 18.0-78.0 m: 42.1 | 384 | 104 | 80 | 24 | D |
| **Gresnigt (2013)** | Feld | 3,4 | USPHS | 19.0-70.0 m: 49.7 | 92 | 20 | 15 | 5 | NM |
| **Karagözoğlu (2016)** | LiDi | 2 | FDI | 18.0-40.0 m: 25.0 | 62 | 12 | 8 | 4 | D |
| **Layton (2012b)** | Feld | 20 | - | 15.0-73.0 m: 41.0 | 499 | 155 | 0,0 | 0,0 | D |
| **Moráguez (2015)** | Alu | - | c/nc | 24.0-79.0 m: 51.0 | 115 | 58 | 33 | 25 | NM |
| **Rinke (2011)** | Alu | 18 | - | / | 272 | 80 | 31 | 41 | St |
| **Selz (2014)** | Alu | 5 | USPHS | 25.0-65.0 m: 40.2 | 149 | 60 | 33 | 27 | NM |

The fabrication of feldspathic porcelain can be done by two methods: the refractory die technique and the platinum foil technique. These methods are sensitive and the fabricated veneer requires careful handling prior to bonding (Layton & Walton, 2012; Malchiodi et al., 2019).

Lithium disilicate is a glass-ceramic with a high concentration of ceramic crystals, which provides a flexural strength similar to enamel ($360 \pm 400$ MPa) and biaxial flexural strength three times greater than feldspathic ceramic. Additionally, it has a low refractive index, which provides translucency, giving a natural and aesthetic appearance. It requires minimal tooth preparation and facilitates adhesive procedures (Malchiodi et al., 2019).

IPS E-max (Ivoclar Vivadent Manufacturing) is a lithium disilicate material that can be machined with computer-aided design/computer-assisted manufacturing or simply pressed. Dentists and technicians can choose the most suitable procedure without compromising biomechanical and aesthetic properties (Alothman & Bamasoud, 2018).

Aluminium oxide ($Al_2O_3$), as a result of the homogeneous framework structure made of ultrafine $Al_2O_3$ particles, whose cavities are filled with a special glass, exhibits a significantly higher tensile bending strength than other ceramic systems (Galindo et al., 2011). Glass-infiltrated alumina (In-Ceram) has a flexural strength of 400 MPa and poor translucency, while high-purity alumina (Procera Allceram) has 650 MPa. This material is highly resistant; however, it has poor aesthetic properties and an opaque appearance due to its refractive index. Therefore, it is only suitable for the fabrication of crown frames with subsequent veneering (Rinke et al., 2011).

## 3.3 Veneers Protocol

In every dental procedure, it is crucial to follow detailed protocols. When making ceramic veneers, it is important to follow certain steps to achieve aesthetic, long-lasting results. The process begins with the diagnosis, determining which patients are suitable candidates for veneers and allowing them to preview the expected outcomes.

The primary steps in an aesthetic treatment include the following steps. First, a clinical examination is conducted to identify the initial problems, such as the presence of multiple unaesthetic restorations, misaligned teeth, and discolorations. Next, preoperative photos are taken from all views (frontal, left and right views, as well as occlusal view).

Subsequently, the shade is selected and primary impressions are taken so that a diagnostic wax-up can be performed. Thereafter, a mock-up is created, providing an accurate representation of the expected final result. The wax-up is essential as it aids patient decision-making, guides the dentist in preparation, and assists in the development of provisional and final work assessments. Gingival corrections, orthodontic treatments, and bleaching must be considered before starting (Cardoso & Dercurio, 2015).

Firstly, the silicone index is placed, and the occlusal view provides controlled tooth preparation involving vestibular, proximal, and cervical preparation with diamond burs. Secondly, isolation with a rubber dam and etching with 35% phosphoric acid etchant gel for 20 seconds is performed according to Alnakib and Alsaady (2021). Dentine and enamel are etched with 35% phosphoric acid for 10-15 seconds in dentine to 30 seconds in enamel, according to another study (Gresnigt et al., 2019). It is paramount to ensure the complete removal of the etching agent, washing thoroughly for at least 20 seconds and drying carefully to protect the collagen network. The etched enamel should appear opaque and clean. The etching agent can also be 37% phosphoric acid for 30 seconds, extended 1 mm over preparation, and rinsed for 60 seconds. Thirdly, a thin layer of bonding agent is applied, rubbed for 20 seconds, then gently air-dried but not light-cured (Linhares et al., 2018).

Five papers on different types of ceramic preparation were found, with the results summarised in **Table 2**. The preparation method depends on the type of ceramic and the concentration of the hydrofluoric acid used. For feldspathic veneers, the inner surface can be etched with 5% hydrofluoric acid for 180 seconds, 9% for 120 seconds, or 10% for 90 seconds. For lithium disilicate, commonly used concentrations are 9.5%, 9.6%, and 10% for 60, 30, and 20 seconds respectively. After etching, all agents should be cleaned with water for at least 30 seconds (Alnakib & Alsaady, 2021).

**Table 2.** Etching time for different ceramic materials with different hydrofluoric acid concentrations. [HFA] = Hydrofluoric acid.

| AUTHOR (YEAR) | CERAMIC TYPE | HFA CONC (%) | TIME (S) | WASH TIME (S) |
|---|---|---|---|---|
| **Alnakib (2021)** | Feldspathic | 5,0 | 180,0 | 30,0 |
| **Gresnigt (2013)** | Feldspathic | 9,0 | 120,0 | 60,0 |
| **Cardoso (2015)** | Feldspathic | 10,0 | 90,0 | phosphoric acid 35% for wash; ultrasonic: 4-10 min |
| **Demerekin (2022)** | Lithium disilicate | 9,5 | 60,0 | 60,0 |
| **Linhares (2018)** | Lithium disilicate | 9,6 | 30,0 | 30.0 s; ultrasonic |
| **Cardoso (2015)** | Lithium disilicate | 10,0 | 20,0 | 30,0 |

Studies by other authors suggested alternative protocols, such as using 35% phosphoric acid for 30 seconds to completely remove hydrofluoric acid and then washing for 30 seconds or using an ultrasonic bath with alcohol for 4 to 10 minutes, though these alternatives extend the protocol duration (Cardoso & Dercurio, 2015; Linhares et al., 2018).

The internal surface of the veneers must appear even and frosted, without debris, white spots, or shiny areas. In all studies, the protocol involved applying silane for 1 minute to enhance substrate wettability and promote reliable adhesion by forming covalent bonds with glass particles (Gresnigt et al., 2013).

For alumina veneers, inner-surface etching is unnecessary, as this material does not respond to hydrofluoric acid and this will not alter its adhesive properties (Cardoso & Dercurio, 2015). A very thin bonding layer can be added and light-cured for 30 seconds, avoiding any interference with the fitting of the veneer.

Once the teeth and ceramics are prepared, dual-curing luting composite is applied to the internal surface of the glass ceramic veneers. This process is applicable only for feldspathic and lithium disilicate veneers, as alumina is not adhesively bonded but rather cemented. The veneer is then placed using light finger pressure or a placement instrument onto the dental area. Excess resin cement is removed with an angled dental probe parallel to the restoration margin, floss, or a curette. Once all margins are correctly filled and free of excess cement, light-curing is performed for 40 seconds on each side (Linhares et al., 2018).

Some authors suggest that the final steps should be completed 24 hours after cementation. Occlusion must be checked, and fine and extra-fine abrasive strips are used to remove excess material and finish the margins (Alnakib & Alsaady, 2021). Glycerin gel applied at the margins ensures oxygen inhibition during polymerization (Gresnigt et al., 2019).

## 3.4 Survival rate and reasons for failure

When considering longevity, survival rates can indicate the behavior of different types of ceramic veneers over time. A total of four papers studied the survival rates of feldspathic veneers over the years. After 10 years, this ceramic type had a survival rate of 95% to 91% (Layton & Walton, 2012b; Dumfahrt & Schäffer, 2000). After 20 years, it decreases to 91% according to Layton et al. (2012a) and Alothman & Bamasoud (2018).

Nine of the 34 articles addressed the survival rates of lithium disilicate ceramic veneers, starting follow-up at six months and extending up to twenty years (**Table 3**). Within less than one year after luting, all lithium disilicate veneers survived (Karagözoğlu et al., 2016). The data show that after 3-4 years, survival decreases to a minimum of 1.3% (Malchiodi et al., 2019), reaching its minimum value of 82.93% after 20 years of masticatory load and exposure to abrasion and acids (Beier et al., 2012).

**Table 3.** Survival rate of feldspathic veneers. [Obs. time] = Observational time; [Surv. rate] = Survival rate.

| AUTHOR (YEAR) | OBS. TIME (YEARS) | SURV. RATE (%) |
|---|---|---|
| **Karagözoğlu (2016)** | 0.5, 1, 2 | 100.0 |
| **Malchiodi (2019)** | 3 | 98.7 |
| **Dederichs (2021)** | 4 | 98.7 |
| **Nejatidanesh (2018)** | 5 | 97.8 |
| **Alnakib (2021)** | 9 | 87.0 |
| **Beier (2012)** | 5 | 94.4, 93.5, 82.9 |
| **Aslan (2019)** | 10 | 97.4 |
| **Demerekin (2022)** | 10 | 93.5 |

Regarding alumina veneers, three studies were compared. The minimum observation time was 9.5 years (Moráguez et al., 2015) and the maximum was 15 years (Rinke et al., 2011), with a survival rate of 87.5% for 163 anterior veneers. In comparison, Galindo et al. (2011) and Moráguez et al. (2015) investigated the same rate in 155 and 58 veneers, respectively. The lowest survival rate corresponds to the study of 155 patients, reporting a result of 68.3% over almost ten years for all kinds of fractures, and 90.9% for critical fractures only.

In dental treatments, despite the use of adequate protocols and high-quality materials, ceramics can fail in various ways, primarily over time. The main reasons for failure include mechanical failure, marginal adaptation failure, and colour-related failures such as discolouration or staining. Mechanical failures include veneer fracture, porcelain chipping, and debonding. When a porcelain veneer fractures, it means that the material cannot be corrected or repaired; this is one of the most complicated failures that can occur. A total of 15 studies evaluated this type of failure: three in feldspathic, seven in lithium disilicate, and four in alumina, as shown in **Table 4**.

**Table 4.** Fracture percentages in different ceramic materials.

| AUTHOR (YEAR) | MATERIAL | TIME (YEARS) | FRACTURE (%) |
|---|---|---|---|
| **Gresnigt (2013)** | Feldspathic | 3,4 | 0,9 % |
| **Dumfahrt (2000)** | Feldspathic | 10,0 | 4,0 % |
| **Gresnigt (2019)** | Feldspathic | 11,0 | 5,0 % |
| **Average** | | 10,5 | 4,7 % |
| **Dederichs (2021)** | Lithium Disilicate | 4,0 | 1,3 % |
| **Sulaiman (2020)** | Lithium Disilicate | 7,5 | 1,3 % |
| **Alnakib (2021)** | Lithium Disilicate | 9,0 | 4,0 % |
| **Aslan (2019)** | Lithium Disilicate | 10,0 | 1,0 % |
| **Demerekin (2022)** | Lithium Disilicate | 10,0 | 6,0 % |
| **Beier (2012)** | Lithium Disilicate | 10,0 | 44,8 % |
| **Arif (2019)** | Lithium Disilicate | 7.0-14.0 | 4,4 % |
| **Average** | | 9,8 | 3,6 % |
| **Moráguez (2015)** | Alumina | 9,5 | 7,0 % |
| **Galindo (2011)** | Alumina | 10,0 | 5,1 % |
| **Selz (2014)** | Alumina | 10,0 | 7,4 % |
| **Rinke (2011)** | Alumina | 18,6 | 14,7 % |
| **Average** | | 9,8 | 6,6 % |

Feldspathic ceramic veneers fractured in 0.9% of cases after 3.4 years and $4-5\%$ after 10-11 years of follow-up. For lithium disilicate veneers, 1.3% fractured four years after cementation and 1% after 10 years (Aslan et al., 2019), with a maximum of 6% (Demerekin & Turkaslan, 2022). The highest fracture percentage is 44.8% (Beier et al., 2012). Concerning alumina, the material fractured at rates of 7% (Moráguez et al., 2015) and 7.4% (Selz et al., 2014) after 9.5 and 10 years, respectively; after 18.6 years, the rate increased to 14.7%, nearly doubling (Rinke et al., 2011). On average, there were 4.7% feldspathic fractures in 10.5 years, 6.6% alumina fractures in 9.8 years, and 3.6% lithium disilicate fractures in 9.9 years.

Chipping, diagnosed as a small broken piece of the ceramic material, was assessed by eight authors in their studies, each focusing on a specific material and different observational periods (**Table 5**). Studies on lithium disilicate found that, on average, 3.6% of the veneers experienced chipping 9.8 years after cementation. For feldspathic veneers, 4% failed in ten and a half years, and only 1% in three years. In the case of alumina veneers, 16.5% were affected by chipping on average over 9.8 years.

**Table 5.** Porcelain chipping percentages in different ceramic materials.

| AUTHOR (YEAR) | MATERIAL | TIME (YRS) | FAILURE (%) |
|---|---|---|---|
| **Arif (2019)** | Lithium Disilicate | 7.0-14.0 | 6,0 % |
| **Beier (2012)** | Lithium Disilicate | 10,0 | 2,0 % |
| **Alnakib (2021)** | Lithium Disilicate | 9,0 | 2,0 % |
| **Average** | | 9,8 | 3,6 % |
| **Gresnigt (2019)** | Feldspathic | 11,0 | 4,0 % |
| **Dumfahrt (2000)** | Feldspathic | 10,0 | 4,0 % |
| **Gresnigt (2013)** | Feldspathic | 3,4 | 1,0 % |
| **Average** | | 10,5 | 4,0 % |
| **Selz (2014)** | Alumina | 10,0 | 13,0 % |
| **Moráguez (2015)** | Alumina | 9,5 | 21,0 % |
| **Average** | | 9,8 | 16,5 % |

Strict protocols for tooth and veneer preparation and cementation are essential to achieve reliable results. If these protocols are not followed, debonding can occur. Seven articles describe how frequently a certain type of ceramic loses its ability to bind to the substrate and when this occurs (**Table 6**). About 2% of feldspathic veneers experienced debonding over an average of 10.5 years, compared to 1.1% of lithium disilicate veneers over 9.5 years. For alumina, the rate was 1.3% over 10 years.

Regarding marginal adaptation, according to the Ryge and USPHS Criteria, a good result is when there is no catch or penetration of the explorer and no visible evidence of a crevice (**Table 7**). After seven to fourteen years of follow-up, 4% of lithium disilicate veneers showed signs of explorer penetration, while feldspathic veneers had a 10% failure rate over 11.5 years. Alumina presented two very different results, 28% in one study (Selz et al., 2014) and 9% in another (Galindo et al., 2011), averaging 19.8% over 10 years.

**Table 6.** Veneer debonding percentages in different ceramic materials.

| AUTHOR (YEAR) | MATERIAL | TIME (Yrs) | FAILURE (%) |
|---|---|---|---|
| **Alothman (2018)** | Feldspathic | 20.0 | 5.0 |
| **Gresnigt (2019)** | Feldspathic | 11.0 | 2.0 |
| **Dumfahrt (2000)** | Feldspathic | 10.0 | 2.0 |
| **Average** | | 10.5 | 2.0 |
| **Aslan (2019)** | Lithium Disilicate | 10.0 | 1.0 |
| **Alnakib (2021)** | Lithium Disilicate | 9.0 | 2.0 |
| **Demerekin (2022)** | Lithium Disilicate | 10.0 | 19.0 |
| **Average** | | 9.5 | 1.1 |
| **Selz (2014)** | Alumina | 10.0 | 1.3 |
| **Average** | | 10.0 | 1.3 |

**Table 7.** Failure percentages in marginal adaptation in different ceramic materials.

| AUTHOR (YEAR) | MATERIAL | TIME (Yrs) | FAILURE (%) |
|---|---|---|---|
| **Arif (2019)** | Lithium disilicate | 7-14 | 4.0 |
| **Gresnigt (2019)** | Feldspathic | 11.0 | 11.0 |
| **Fradeani (2005)** | Feldspathic | 12.0 | 7.9 |
| **Gresnigt (2013)** | Feldspathic | 3.4 | 4.0 |
| **Selz (2014)** | Alumina | 10.0 | 28.0 |
| **Galindo (2011)** | Alumina | 10.0 | 9.0 |

The need for treatment in anterior teeth often arises due to their unaesthetic appearance, making colour an important parameter to observe in aesthetic restorations, both at the time of selection and after several years of use. Marginal discolouration and staining are criteria included in this chapter, and patient satisfaction is often dictated by colour. To evaluate these aspects, seven articles were reviewed: two for lithium disilicate, three for feldspathic, and two for alumina (**Table 8**). Approximately 16.7% of feldspathic restored teeth showed marginal discolouration after an average of 11 years of use, while lithium disilicate veneers failed at a similar rate of 16.7% over 9.5 years. For alumina veneers, 17.4% exhibited this problem over an average of 9.8 years.

Surface stains can develop after prolonged exposure to pigments found in food, drinks, tobacco, etc., and such changes in veneers would be considered a failure. For example, 1% of alumina veneers revealed stains after 9.5 years, compared to 3.39% of feldspathic veneers over 12 years. The study by Elter et al. (2021) observed lithium disilicate veneers in a laboratory setting rather than over years; they found that 5% of the veneers showed perceptible stains after immersion in a coffee solution.

**Table 8.** Marginal discoloration in different ceramic materials.

| AUTHOR (YEAR) | MATERIAL | TIME (Yrs) | FAILURE (%) |
|---|---|---|---|
| **Beier (2012)** | Lithium disilicate | 10.0 | 18.0% |
| **Alnakib (2021)** | Lithium disilicate | 9.0 | 1.0% |
| **Average** | | 9.5 | 16.7% |
| **Gresnigt (2019)** | Feldspathic | 11.0 | 18.0% |
| **Fradeani (2005)** | Feldspathic | 12.0 | 13.6% |
| **Dumfahrt (2000)** | Feldspathic | 10.0 | 17.0% |
| **Average** | | 11.0 | 16.7% |
| **Selz (2014)** | Alumina | 10.0 | 30.0% |
| **Moráguez (2015)** | Alumina | 9.5 | 1.0% |
| **Average** | | 9.8 | 17.4% |

A total of nine authors examined the presence or absence of secondary caries several years after the cementation of ceramic materials. Most of the articles evaluated the data over a ten-year period (**Table 9**). The statistical table below indicates that lithium disilicate material presented 2% incidence of caries at the margins within a period of 7 to 14 years.

Beier et al. (2012) reported similar results (3%), while the study by Demerekin et al. (2022) reported higher failure rates (19%) over ten years. Conversely, authors studying feldspathic veneers found that only 1% of the evaluated patients were diagnosed with caries in nearly 11.5 years.

Finally, alumina veneers demonstrated similar low values of caries (5%) within 10 years, as shown by Selz et al. (2014). According to Rinke et al. (2011), nearly eight years after cementation, 3% of the patients presented secondary caries.

**Table 9.** Percentages of secondary caries in different ceramic materials.

| AUTHOR (YEAR) | MATERIAL | TIME (Yrs) | FAILURE (%) |
|---|---|---|---|
| **Arif (2019)** | Lithium disilicate | 7.0-14.0 | 2.0 |
| **Beier (2012)** | Lithium disilicate | 10.0 | 3.0 |
| **Demerekin (2022)** | Lithium disilicate | 10.0 | 19.0 |
| **Average** | | 10.2 | 2.7 |
| **Gresnigt (2019)** | Feldspathic | 11.0 | 1.0 |
| **Dumfahrt (1999)** | Feldspathic | 10.0 | 1.0 |
| **Gresnigt (2013)** | Feldspathic | 3.4 | 0.0 |
| **Average** | | 10.5 | 1.0 |
| **Selz (2014)** | Alumina | 10.0 | 5.0 |
| **Moráguez (2015)** | Alumina | 9.5 | 0.0 |
| **Rinke (2011)** | Alumina | 18.0 | 3.0 |
| **Average** | | 9.8 | 2.8 |

# 4 Discussion

The objective of this study is to describe the characteristics and protocols of feldspathic, lithium disilicate, and alumina veneers, and to compare their survival rates and specific failures over time.

Concerning the techniques and protocols, they are very similar for the glass-ceramic types of veneers. Nevertheless, the etching time with 10% hydrofluoric acid is shorter for lithium disilicate than for feldspathic veneers. This implies that during the preparation of restorations for cementation, chair-time can be reduced, especially when performing a full smile design (Sá et al., 2018).

Regarding survival rates, the three materials exhibit very high survival rates. From six months to 2 years, all veneers survived. After 5 years, survival rates decreased by 2.2 percentage points. In 10-year follow-ups, results are very similar; however, the percentage of alumina was slightly lower than feldspathic or lithium disilicate. From ten years onwards, lithium disilicate veneers exhibited higher survival rates compared to feldspathic and alumina veneers.

Differences in survival rates are also related to patient habits or previous treatments. For instance, having parafunctional habits or pre-existing large restorations reduces veneer success. However, factors related to the operator are also determinant. Independent of veneer type, clinical experience is always a key factor for survival probability (Shaini et al., 1997).

The evaluation criteria for durability consider the following types of failure: fracture, chipping, debonding, marginal adaptation, marginal discolouration, staining, and secondary caries. Fracture is one of the most common reasons for veneer replacement and significantly affects patient satisfaction with the treatment. Despite the excellent characteristics of ceramic veneers, fracture remains the primary cause of absolute failure, necessitating the repetition of the procedure from the beginning (Nejatidanesh et al., 2018).

Alumina veneers demonstrated a low fracture rate in ten-year follow-ups, similar to feldspathic veneers. Lithium disilicate presents greater strength and therefore less fracture incidence than other materials, while feldspathic is more susceptible in cases of diastema closure or where large areas with unsupported material need to be covered, which are cases of higher mechanical stress.

The results indicate that lithium disilicate has high fracture resistance except in the study by Beier et al. (2011), which evaluated the survival rate in patients diagnosed with bruxism. This investigation showed that half of the veneers failed in such patients. These results are significant because all three ceramic veneers can remain intact at high percentages after 10 years, provided the patient selection is correct and they do not suffer from any parafunctional habits, notably bruxism, which leads to higher failure rates.

Galindo et al. (2011) and Moráguez et al. (2015) both had similar observation periods for alumina veneers, but very dissimilar results. The discrepancy occurred because Moráguez et al. (2015) analysed the data using their own parameters and ratings (critical/non-critical), obtaining the lowest results (68.3%) in the parameter that included all types of fractures. If considering only critical fractures, the survival rate results were very similar to Galindo's study (90.9%).

Concerning chipping, lithium disilicate veneers exhibited a higher rate than feldspathic veneers over ten years, while alumina veneers showed the highest percentages. Chipping, especially at the edges, can be related to occlusal interference in the posterior region, independent of the material (Dumfahrt & Schäffer, 2000).

Overall, the three types of veneers had minimal debonding rates after ten years (1-2%). When debonding occurs, it is often because success is directly related to the tooth substrate where the veneers are placed. Adhesion is much more effective in enamel compared to dentine. Failure rates also increase when veneers cover existing composite restorations. Thus, the more dentine exposed or composite restorations present, the higher the challenge of achieving effective adhesion (Dumfahrt & Schäffer, 2000).

In the only study that reported significant debonding (19%), lithium disilicate veneers were placed in patients diagnosed with fluorosis, implying that dental enamel defects could have affected adhesive cementation (Demerekin & Turkaslan, 2022).

Therefore, it is crucial to preserve as much enamel as possible during tooth preparation because an increased quantity of exposed dentine becomes a risk factor not only for debonding but also for fracture. This is due to the flexibility of dentine compared to the high stiffness of the materials (Rinke et al., 2020). This is in accordance with other studies that determined that dental preparation must be restricted to the enamel in order to obtain long-term success (Sá et al., 2018).

With reference to marginal adaptation, in 3.4 years feldspathic veneers had low failure rates, then in an average of ten years, it increases. In seven to fourteen years, lithium disilicate has the lowest failure rate. In ten years, alumina exhibited a high average percentage of marginal misfit compared to the other materials. Marginal adaptation can be influenced by the material chosen in its elaboration process. The difference in the marginal gap is attributed to the manufacturing type. Feldspathic veneers constructed by the refractory die technique suffer more distortion than alumina that is sintered (Ghaffari et al., 2016).

One author's results differ, showing a high percentage of failure in alumina veneers. Nonetheless, the maladaptation in alumina was not so serious. According to the USPHS criteria and clinical parameters for classification of marginal adaptation, the effects of this failure involved neither veneers' mobility nor retention of the explorer, which could have been the worst ratings on the assessment (Selz et al., 2014). Moreover, the results showed that the process of marginal discoloration is higher in alumina veneers. The other two materials had the same average percentage, with lithium disilicate in 9.5 years and feldspathic in 11 years of follow-up.

In feldspathic and lithium disilicate, staining rates are low even after twelve years. Interestingly, alumina shows less staining of all materials, which means maintenance of the aesthetics and patient satisfaction are superior. Possible causes for staining may be food and beverages such as tea or coffee, but the only study that found this to be the case was conducted under laboratory conditions using a longer immersion in coffee, which is not realistic in daily life. What is more apparent in staining is the role of the cement type. In the same study, it was shown that colour change is caused in most cases by the internal discoloration of the resin composite luting agent by a hydrolytic reaction. Moreover, patients' poor oral hygiene can also cause gum receding resulting in exposure to a line of cement and stains in any veneer material (Elter et al., 2021).

Concerning secondary caries, all types of veneers showed very small percentages. Feldspathic veneers revealed insignificant numbers in 10.5 years. During the same follow-up period, lithium disilicate presents similar behaviour, apart from Demerekin and Turkaslan (2022) who show a much higher risk of cavities in fluorosis patients. The justification for that is that tooth structure presents roughness that can be more prone to caries. Alumina veneers had the highest percentage of secondary caries.

In comparison to these three materials, it can be mentioned that the material must be carefully chosen depending on the case. Due to high glass contents in feldspathic veneers, they provide excellent aesthetic properties, although this can initiate early cracks that lead to future fractures. This fragility could affect the appearance of the veneer because cement will be exposed and can stain the margins. In cases of higher risk such as diastema closure or severe attrition, where wider areas have to be covered, it is recommended to select lithium disilicate veneers. This material is suitable due to its high flexural strength. Finally, alumina has great marginal adaptation but poor aesthetic characteristics. Therefore, it is only suitable for the fabrication of crown frames with subsequent veneering.

As with all other studies, the current study is subject to limitations. For instance, none of the analysed articles compared these three materials simultaneously, but most compare only two, namely feldspathic and lithium disilicate, or each material separately, which makes the comparison more difficult. The parameters analysed and the reported data were heterogeneous, which made it difficult to interpret the results.

## Conclusions

In conclusion, debonding, staining, and secondary caries were rare complications compared to fracture, chipping, and discolouration, which are slightly more frequent. Regardless of the material type, all veneers exhibited high survival rates.

The durability and appearance are related not only to optimal patient and material selection but also to tooth preparation, adhesion to the substrate, protocol precision, operator expertise, the patient's habits, and tooth diseases.

Assessing the different veneers is challenging in determining the most suitable option for all cases. The comprehensive success and reliability of aesthetic treatment depend on several factors. The studies are very heterogeneous in follow-up periods and evaluation criteria; therefore, it is difficult to provide a definitive recommendation. In view of this limitation, lithium disilicate veneers demonstrated better performance than the other two materials.


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## Ethical approval

No ethical approval was required for this study as it did not involve human participants, animal subjects, or sensitive data. This study falls under the category of data collection without participant identification.

## Consent for publication

Not applicable.

## Authors' contributions

The author(s) declare that all the criteria for authorship designated by the International Committee of Medical Journal Editors have been met. More specifically, these are: (a) Substantial contributions to the conception or design of the work; or the acquisition, analysis, or interpretation of data for the work; AND (b) Drafting the work or revising it critically for important intellectual content; AND (c) Final approval of the version to be published; AND (d) Agreement to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

## Competing interests

The author(s) declare that there are no competing interests related to this work.

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# References


Alenezi, A., Alsweed, M., Alsidrani, S., & Chrrcanovic, B. R. (2021). Long-term survival and complication rates of porcelain laminate veneers in clinical studies: A systematic review. Journal of Clinical Medicine, 10(5), 1074.

Alnakib, Y., & Alsaady, A. (2021). Influence of ceramic and substrate types on the microleakage of aged porcelain laminate veneers. Clinical, Cosmetic and Investigational Dentistry, 13, 67-76.

Alothman, Y., & Bamasoud, M. S. (2018). The success of dental veneers according to preparation design and material type. Macedonian Journal of Medical Sciences, 6(12), 2402-2408.

Arif, R., Dennison, J. B., Garcia, D., & Yaman, P. (2019). Retrospective evaluation of the clinical performance and longevity of porcelain laminate veneers 7 to 14 years after cementation. The Journal of Prosthetic Dentistry, 121(1), 31-37.

Aslan, Y. U., Uludamar, A., & Özkan, Y. (2019). Retrospective analysis of lithium disilicate laminate veneers applied by experienced dentists: 10-year results. The International Journal of Prosthodontics, 36(6), 471-474.

Attia, Y. S., Sherif, R. M., & Zaghloul, H. H. (2021). Survival of hybrid laminate veneers using two different tooth preparation techniques: Randomized clinical trial. Brazilian Dental Journal, 32(6), 36-53.

Beier, U. S., Kapferer, I., & Dumfahrt, H. (2012). Clinical performance of porcelain laminate veneers for up to 20 years. The International Journal of Prosthodontics, 25(1), 79-85.

Cardoso, P., & Dercurio, R. (2015). Carillas, lentes de contacto y fragmentos cerámicos. Brasil: Editora Ponto 1era Edición.

Dederichs, M., Fahmy, M. D., An, H., Guentsch, A., Viebranz, S., & Kuepper, H. (2021). Comparison of wear resistance of prefabricated composite veneers versus ceramic and enamel. Journal of Prosthodontics: Official Journal of the American College of Prosthodontists, 30(8), 711-719.

Demerekin, Z. B., & Turkaslan, S. (2022). Laminate veneer ceramics in aesthetic rehabilitation of teeth with fluorosis: A 10-year follow-up study. BMC Oral Health, 22(1), 42.

Dumfahrt, H., & Schäffer, H. (2000). Porcelain laminate veneers. A retrospective evaluation after 1 to 10 years of service: Part II–clinical results. The International Journal of Prosthodontics, 13(1), 9-18.

Dumfahrt, H. (1999). Porcelain laminate veneers. A retrospective evaluation after 1 to 10 years of service: Part I–clinical procedure. The International Journal of Prosthodontics, 12(6), 505-513.

Elter, B., Aladağ, A., Çömlekoğlu, M., Çömlekoğlu, M. D., & Kesercioğlu, A. (2021). Colour stability of sectional laminate veneers: A laboratory study. Australian Dental Journal, 66(3), 314-323.

Fradeani, M., Redemagni, M., & Corrado, M. (2005). Porcelain laminate veneers: 6-to 12-year clinical evaluation–a retrospective study. The International Journal of Periodontics & Restorative Dentistry, 25(1), 9-17.

Galindo, M. L., Sendi, P., & Marinello, C. P. (2011). Estimating long-term survival of densely sintered alumina crowns: A cohort study over 10 years. The Journal of Prosthetic Dentistry, 106(1), 23-28.

Ghaffari, T., Hamedi-Rad, F., & Fakhrzadeh, V. (2016). Marginal adaptation of Spinell In-Ceram and feldspathic porcelain laminate veneers. Dental Research Journal, 13(3), 239-244.

Gresnigt, M. M., Kalk, W., & Özcan, M. (2013). Clinical longevity of ceramic laminate veneers bonded to teeth with and without existing composite restorations up to 40 months. Clinical Oral Investigations, 17(3), 823-832.

Gresnigt, M., Cune, M., Schuitemaker, J., van der Made, S., Meisberger, E., Magne, P., & Özcan, M. (2019). Performance of ceramic laminate veneers with immediate dentine sealing: An 11 year prospective clinical trial. Dental Materials, 35(7), 1042-1052.

Karagözoğlu, I., Toksavul, S., & Toman, M. (2016). 3D quantification of clinical marginal and internal gap of porcelain laminate veneers with minimal and without tooth preparation and 2-year clinical evaluation. Quintessence International, 47(6), 461-471.

Malchiodi, L., Zotti, F., Moro, T., De Santis, D., & Albanese, M. (2019). Clinical and esthetical evaluation of 79 lithium disilicate multilayered anterior veneers with a medium follow-up of 3 years. European Journal of Dentistry, 13(4), 581-588.

Moráguez, O. D., Wiskott, H. A., & Scherrer, S. S. (2015). Three- to nine-year survival estimates and fracture mechanisms of zirconia-and alumina-based restorations using standardized criteria to distinguish the severity of ceramic fractures. Clinical Oral Investigations, 19(9), 2295-2307.

Morimoto, S., Albanesi, R. B., Sesma, N., Agra, C. M., & Braga, M. M. (2016). Main clinical outcomes of feldspathic porcelain and glass-ceramic laminate veneers: A systematic review and meta-analysis of survival and complication rates. The International Journal of Prosthodontics, 29(1), 38-49.

Nejatidanesh, F., Savabi, G., Amjadi, M., Abbasi, M., & Savabi, O. (2018). Five-year clinical outcomes and survival of chairside CAD/CAM ceramic laminate veneers: A retrospective study. Journal of Prosthodontic Research, 62(4), 462-467.

Rinke, S., Bettenhauser-Hartung, L., Leha, A., Roediger, M., Schmalz, G., & Ziebolz, D. (2020). Retrospective evaluation of extended glass-ceramic laminate veneers after a mean observational period of 10 years. Journal of Esthetic and Restorative Dentistry, 32(5), 487-495.

Rinke, S., Tsigaras, A., Huels, A., & Roediger, M. (2011). An 18-year retrospective evaluation of glass-infiltrated alumina crowns. Quintessence International, 42(8), 625-633.

Sá, T. C., Figueired de Carvalho, M. F., de Sá, J. C., Magalhaes, C. S., Moreira, A. N., & Yamauti, M. (2018). Esthetic rehabilitation of anterior teeth with different thicknesses of porcelain laminate veneers: An 8-year follow-up clinical evaluation. European Journal of Dentistry, 12(4), 590-593.

Selz, C. F., Strub, J. R., Vach, K., & Guess, P. C. (2014). Long-term performance of posterior In-Ceram alumina crowns cemented with different luting agents: A prospective, randomized clinical split-mouth study over 5 years. Clinical Oral Investigations, 18(6), 1695-1703.

Shaini, F. J., Shortall, A. C., & Marquis, P. M. (1997). Clinical performance of porcelain laminate veneers. A retrospective evaluation over a period of 6.5 years. Journal of Oral Rehabilitation, 24(8), 554-559.

Sulaiman, T. A., Abdulmajeed, A. A., Delgado, A., & Donovan, T. (2020). Fracture rate of 188,695 lithium disilicate and zirconia ceramic restorations after up to 7.5 years of clinical service: A dental laboratory survey. The Journal of Prosthetic Dentistry, 123(6), 807-810.