

Factors influencing the colour stability of ceramic veneers

A systematic review

Ahmed Ibrahim BESROUR

Dissertação conducente ao **Grau de Mestre em Medicina Dentária (Ciclo Integrado)**

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Trabalho realizado sob a Orientação de
Prof. Doutora Maria do Pranto Valente Braz

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Thanks

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To all, my sincere thanks.

RESUMO

Introdução: A manutenção do sucesso estético a longo prazo das facetas cerâmicas depende da compreensão dos fatores que contribuem para a estabilidade da cor.

Objetivo: Investigar os fatores que podem influenciar a estabilidade da cor a longo prazo de facetas cerâmicas.

Materiais e método: Esta revisão sistemática foi realizada na base de dados PubMed. Foi conduzido de acordo com o Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA), 2020.

Resultados: Dos 70 estudos encontrados nesta busca, apenas 18 atenderam aos critérios de inclusão. 60% dos estudos incluídos nesta revisão sistemática receberam classificação forte para avaliação de qualidade. As alterações de cor das facetas cerâmicas podem ser causadas por fatores intrínsecos e/ou extrínsecos que comprometem os resultados estéticos.

Discussão: Existe consenso que fatores intrínsecos como a espessura da cerâmica, a composição do cimento resinoso, o modo de polimerização e fatores extrínsecos como coloração por absorção de corantes de fontes exógenas podem influenciar a estabilidade da cor das facetas cerâmicas.

Conclusão: Para a estabilidade da cor a longo prazo de facetas cerâmicas, o grau de conversão e a eficiência de polimerização são mais significativos do que a escolha entre os modos de polimerização.

O sistema foto-iniciador é um fator que é preciso ter em conta durante polimerização, sendo recomendado também fotoativar previamente o adesivo dentário. Além disso, os cimentos resinosos combinando Ivocerin e TPO demonstraram maior estabilidade de cor.

Palavras-chave: Colour, Dental Veneers, Dental Ceramics, Stability.

ABSTRACT

Introduction: Maintaining long-term aesthetic success of ceramic veneers is depending on understanding the factors contributing to color stability.

Objectives: To investigate the factors that may influence the long term colour stability of ceramic veneers.

Materials and method: This systematic review was conducted in the PubMed database. It was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA),2020 .

Results: Of the 70 studies found in this search, only 18 met the inclusion criteria. 60% of the studies included in this systematic review received a strong rating for quality assessment. Colour changes in ceramic veneers can be caused by intrinsic and/or extrinsic factors that compromise aesthetic results.

Discussion: There is a consensus that intrinsic factors such as the thickness of the ceramic, the composition of the resin cement, the mode of polymerization and extrinsic factors such as colouring due to staining by absorption of colorants from exogenous sources can influence the colour variation of ceramic veneers.

Conclusion: For long term colour stability of ceramic veneers, the degree of conversion and polymerization efficiency are more significant than the choice between the dual and light modes of polymerization.

The included photo-initiator system is a factor a clinician needs to be aware of while using light mode. It is also advised to photoactivate dental adhesive beforehand. In addition, resin cements combining Ivocerin and TPO demonstrated increased colour stability.

Keywords: Colour, Dental Veneers , Dental Ceramics, Stability.

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1. Introduction

Over the past few years, there has been a growing trend of patients expecting high aesthetic restorations.

Colour stability is a crucial clinical aspect when it comes to the aesthetics outcomes which in turn affects the long-term clinical success of ceramic bonded restorations.

Colour variation overtime is a main problem of adhesive resin cements used for assembling ceramic veneers. This discoloration is especially important at the margins of the ceramic partial coverage restoration (1).

Ceramic laminate veneers have been shown to be a successful method for treating discoloured, malformed, worn, or fractured teeth in visible areas. They have a high rate of long-term success (2).

Almeida JR et al concluded that resin luting agents may influence the colour stability of ceramic veneers bonded to enamel, and dual polymerizing resin-based cement have higher colour variation than the light-polymerizing cement (2).

In order to investigate colour stability, artificial accelerated aging has been utilized in some studies (3).

This method involves exposing the material to a variety of conditions, such as UV light, temperature changes, and water storage in order to simulate clinical conditions.

Colour alterations can be assessed visually or with colour-measuring devices such as colorimeters and spectrophotometers. These instruments are characterized by accuracy and numerical expression of colour.

Colour evaluation can also be based on reliable scores such as CDA aesthetic score and USPH score (4).

Achieving aesthetic durability of ceramic veneers depends on understanding several factors that can contribute to stable color.

2. Objective

The aim of this systematic review is to investigate the factors that affect the long-term colour stability of Ceramic Laminate veneers.

3. Materials and methods

3.1. Protocol developed

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA).

The preferred reporting items for systematic reviews and meta-analyses (PRISMA) was developed to facilitate transparent and complete reporting of systematic reviews and has been updated to PRISMA 2020 to reflect recent advances in systematic review methodology and terminology (6).

Level of evidence and grade of recommendation: The selected studies were evaluated according to the recommendation grading of the effective public health practice project (EPHPP) quality assessment tool (Table 4, Table 5)(5).

3.2. Question criteria

The PICO (Patient, Intervention, Comparison, Outcome) framework is commonly used to develop focused clinical questions for quantitative systematic reviews.

A modified version , PICo , can be used for qualitative questions (figure 1).

The criteria applied to the PICo question are:

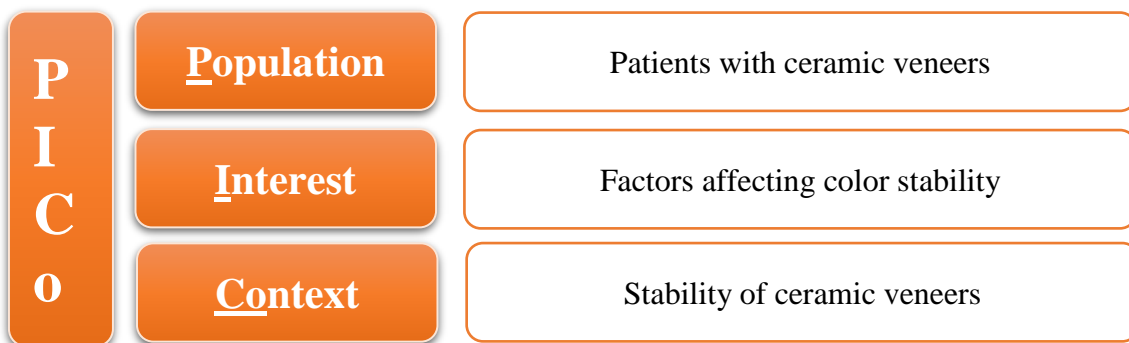


Figure 1 – PICo methodology for developing the research qualitative question

3.3. PICo question

PICo methodology research question:

What are the factors affecting (Co) the color stability (I) of ceramic laminate veneers (P)?

3.4. Search Strategy

The bibliographic research was carried out using the PubMed database between January 1st 2012 and January 1st of 2024, with the last search being conducted on January 1st 2024. A period of 12 years was defined for inclusion of studies (2012-2024).

3.5. Mesh Terms

An advanced search was carried out using Mesh terms in the data base with different combinations (Table 2).

Duplicate articles were removed using the Zotero citation tool.

Table 1 – keywords search results.

Database	Search strategy	Articles identified	Articles selected
PubMed	((colour) AND (dental veneers)) AND (dental ceramics)	33	5
PubMed	((dental veneers) AND (colour))AND(stability)	7	1
PubMed	((dental ceramics) AND (colour))AND (stability)	23	3
PubMed	((colour) AND (dental veneers) AND (dental ceramics)) AND (stability)	7	1
Manual research	((colour) AND (dental veneers) AND (dental ceramics)) AND (stability)		8
TOTAL		70	18

3.6. Inclusion and exclusion criteria

All included articles were read and evaluated individually according to the inclusion and exclusion criteria (Table 2).

Table 2 – Inclusion and exclusion criteria.

Inclusion criteria	Exclusion criteria
Clinical trials	Systematic reviews
Randomized Controlled Trials	Meta-analyses
Controlled Clinical Trials Pragmatic Clinical Trials	Case reports
Comparative studies	Literature reviews
Articles published between 01/01/2012 and 01/01/2024	Unclear or poorly written randomization process. Papers published outside the specified period of time.
Papers published in English	Papers published in languages other than English

3.7. Data extraction and analysis

The titles and abstracts of the relevant articles were assessed by two independent reviewers (D,N) and (A,B) based on the eligibility criteria.

If the abstract did not provide enough information to determine whether a study should be included or excluded, the reviewers read the full text of the article.

Any disagreement about whether a study should be included was resolved through discussion and agreement. Additionally, the two reviewers independently analyzed the full text of the manuscripts that potentially met the selection criteria.

A checklist was used to extract the relevant information and include the following items:

- 1- Article identification (title, author, journal, year of publication)
- 2- Study design
- 3- Objective of the study
- 4- Characteristics of the studied ceramic laminate veneers
- 5- Factors affecting the color stability
- 6- Results
- 7- Level of evidence and Grade of recommendation
- 8- Quality assessment
- 9- Author's conclusions

4. Results

4.1. Results of the database search

The initial search resulted in the identification of 70 articles. Table 2 –22 of the 70 articles identified were eliminated due to duplication using the Zotero Citation Manager.

Of the remaining 48 articles, 29 were eliminated by reading the title and abstract, as they did not meet the eligibility criteria. Only 19 articles were selected through full-text evaluation.

After fully reading the articles, only 10 articles were selected applying the contents defined by the inclusion and exclusion criteria in the advanced data search in PubMed using the conjugations of “Mesh Terms”.

8 articles that were found through a manual search of the bibliography were also added since they have been considered pertinent.

The selection result resulted in 18 articles (Figure 2).

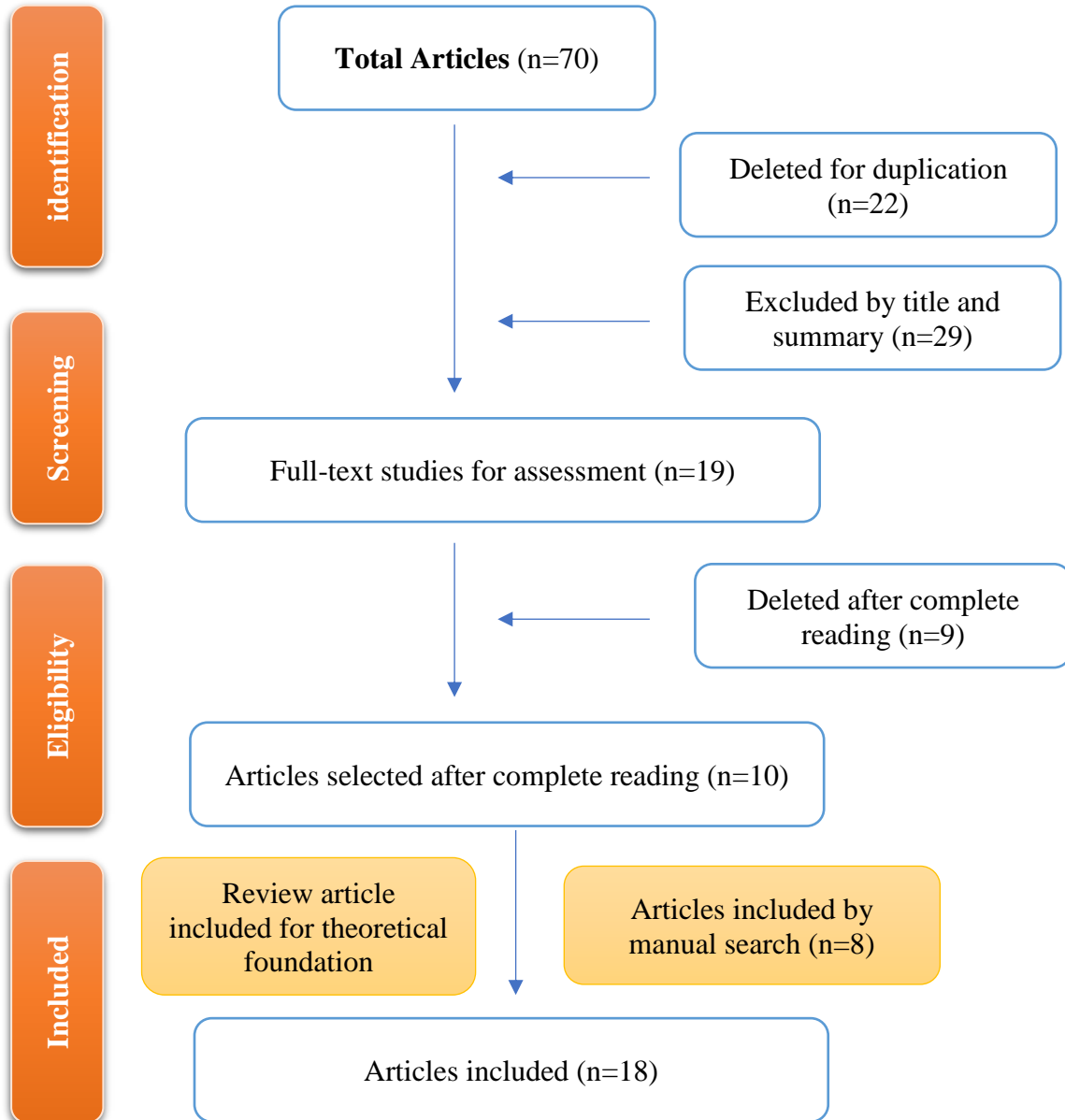


Figure 2 - Search Strategy Flowchart

4.2. Characteristics of the studies

In the qualitative assessment regarding the research design, the following proportions were found (Figure 3):

- Randomized controlled trial (33%);
- Comparative studies (33%);
- Longitudinal study (33%) ; as shown in the following graph.

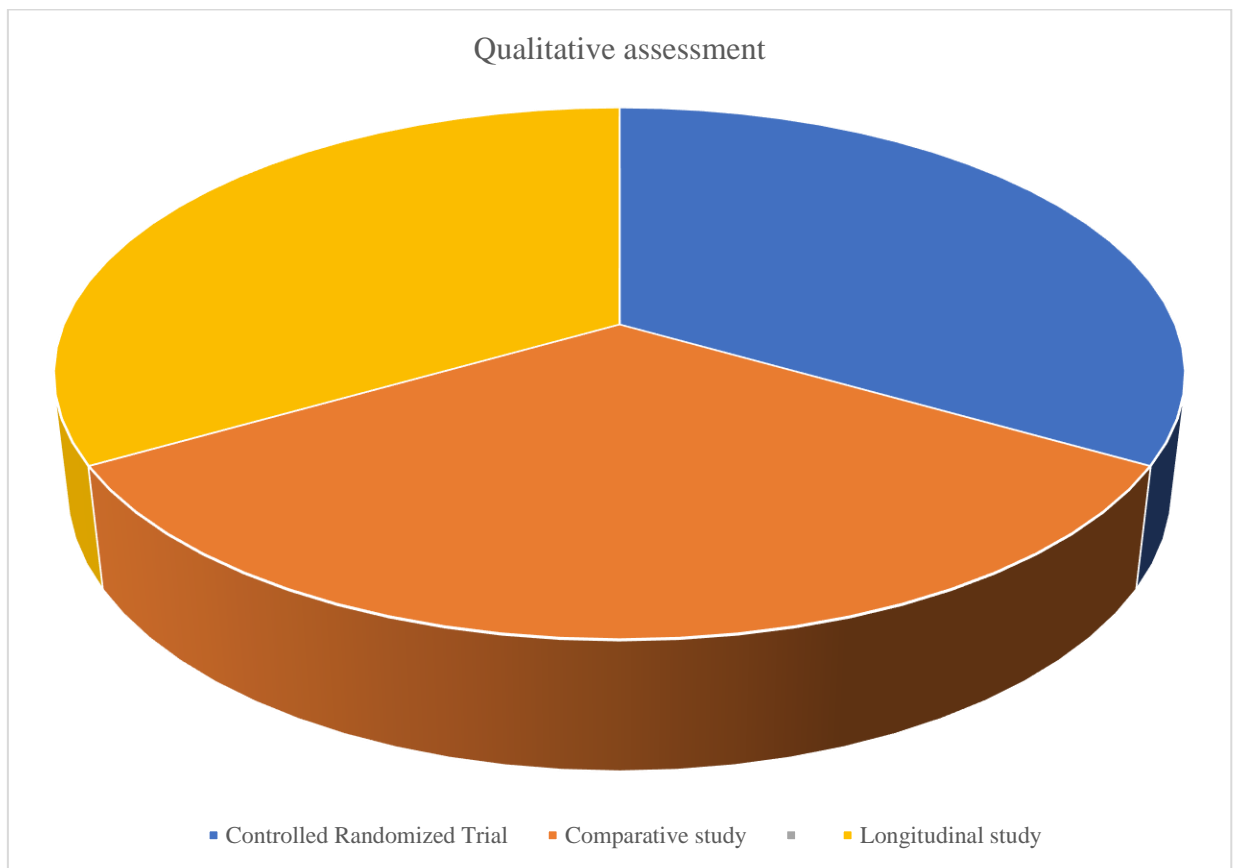


Figure 3 – Classification diagram by type of study

A data extraction table was developed. This table (Table 3) contains information such as article, type of study, objective or materials and methods, results, and conclusion.

Table 3: Table of relevant data from selected articles

Authors, year	Study design	Objectives	Population	Results	Conclusion
Khalap SD et al,2021 (6).	Comparative study	Investigate the influence of different cements and ceramic thickness on final shade and colour stability of ceramic veneers.	3 groups of 60 disc shaped specimens of High translucency (HT) A2 shade of two thickness (0,5mm and 1 mm) randomly used with 03 groups of resin cements (Group A:light cure resin cement -Group B: base paste of dual-cure resin cement -Group C:dual-cure resin cement).	Variolink N base cement showed maximum long term discoloration Increasing the thickness of ceramic veneers reduces long term discoloration.	The type of resin cement and the ceramic thickness affect the color stability of ceramic veneers.
Bagis B et al ,2013 (7).	Comparative study	Investigate the influence of aging on the optical properties of laminate restorations.	60 specimens were prepared from e.max Press, e.max CAD, Empress, Esthetic, e.max Ceram, Inline, and ZirPress systems.	None of the full-ceramic systems were able to match the color of the shade guide. The chemical structures of the ceramic systems were more effective in determining the optical parameters than the fabrication techniques.	Aging caused full-ceramics to become more opaque, darker, reddish and yellowish.

Authors, year	Study design	Objectives	Population	Results	Conclusion
Karaokutan I et al , 2023 (8).	Randomized controlled trial	Comparison of the colour change on veneers, made of two different types of ceramics material, after artificial accelerated aging bonding with conventional dual-cure, amine-free dual-cure or light cure resin cements.	90 laminate veneers bonded in 90 non-carious human teeth using 03 different resin cements. Prepared teeth were randomly divided into 3 groups (n=30): <ul style="list-style-type: none"> • lithium disilicate ceramic • lithium disilicate ceramic with high-density micronization, • zirconia-reinforced lithium silicate ceramic. Each Ceramic veneers group was divided into 03 groups (n=10) according to the luting cement type: <ul style="list-style-type: none"> • light-cure resin cement • amine-free dual-cure resin cement • conventional dual-cure resin cement 	Colour changes observed on The Zirconia reinforced lithium disilicate veneers and lithium disilicate veneers are similar. The amine-free dual-cure resin cement showed a similar color change as light-cure resin cement.	The composition of the materiel has no effect on color stability of ceramic veneers.
Magalhães AP et al ,2014 (9).	Comparative study	Evaluate the influence of resin luting cement's activation mode in the final shade of laminate veneers after accelerated artificial aging (AAA).	10 laminate veneers bonded on bovine teeth with light-cured resin cement. 10 laminate veneers bonded on bovine teeth with dual cured resin cement.	No relevant differences between the two activation mode in terms of color change.	Activation mode has no effect on long term color stability of ceramic veneers.

Authors, year	Study design	Objectives	Population	Results	Conclusion
Qaraghuli AM et al ,2022 (10).	Randomized controlled trial	Assess the color stability of different esthetic veneer restorative materials following exposure to potentially-staining commonly consumed beverages.	15 blocks of machinable feldspathic ceramic. 15 blocks of zirconia reinforced lithium silicate glass ceramic 15 blocks of hybrid ceramics 15 blocks of micorparticle composite resin.	Color change are significant when the restorations are exposed to staining beverage.	Staining commonly consumed beverages significantly alter the color of the investigated restorative materials.
Kilinc H et al ,2017 (11).	Comparative study	Investigate the influence of differents polishing/ procedures on the long-term stability of optical properties of esthetic CAD-CAM materials.	150 specimens of lava ultimate, cerasmart, vita enamic, vita supranity and vita Mark II.	Optical properties of CAD/CAM materials can be affected by the material type and surface treatment procedure.	Manual polishing or glazing is highly recommended for long term color stability of ceramic veneers.
<u>Marchionatti AME</u> et al, 2017 (12).	Controlled Randomized Clinical Trial	Evaluation of color change and marginal discoloration of dual- and light-polymerizing cement used for ceramic laminate veneers.	In 10 participants, 0.3-mm-thick ceramic laminate veneers were cemented on the buccal surface of the second premolars without tooth preparation.	For all evaluated specimens the results was similar for both light- and the dual-polymerizing modes. Marginal discoloration increased over a 2-year period for both the light- and the dual-polymerizing modes.	Mode of polymerization did not affect color stability of ceramic laminate veneers. The thinner the restoration thicknes , the greater the changes when conventional dual and light-cured cements are used.

Authors, year	Study design	Objectives	Population	Results	Conclusion
Gugelmin BP et al,2020 (13).	Longitudinal study	Assessment of the color stability of ceramic veneers luted with resin cements and pre-heated composite resins (60°C) for 12 months.	10 thick lithium-silicate-glass-ceramic laminated veneers (0.8-mm) were bonded on 10 specimens of bovine enamel using different types of resin cements . Two resin cements (AllCem Veneer, light-cured and AllCem, dual-cured and three composite resins were used.	The different materials used for cementation of thin ceramic veneers influenced the final color of the restorations.	The light-cured and dual-cured resin cements had similar color stability. Heating did not affect the color stability of the composite resins used.
Lee SM et al ,2018(14).	Longitudinal study	Assesment of the colour stability of laminate veneers after accelerated aging using different ceramic and resin cement systems.	Ceramic specimens: (N=168-shade A1;- Thickness, 0.50 ±0.05 mm;-Diameter, 10.00 ±0.10 mm) were used (high translucency [HT] to low translucency [LT]) ceramics. Light polymerizing and dual polymerizing resin cements were used.	High translucent lithium disilicate glass ceramic exhibited a greater tendency for long term color changes of ceramic veneers. Lower brightness of resin cement provides higher color stability.	Trenslucency of ceramic materiel negatively affect the color stability of ceramic veneers, Mealwhile brightness of resin cement have positive effect.

Authors, year	Study design	Objectives	Population	Results	Conclusion
Almeida JR et al,2015 (2).	Longitudinal study	Investigate the effects of resin-based agents and aging on the color stability of ceramic veneers.	Ceramic disks were cemented to (n=10) bovine enamel disks using 4 resin-based luting agents: - Dual-polymerizing cement (RelyX ARC) - Light-polymerizing cement (RelyX Veneer). - Flowable composite resin (Filtek Z350 Flow) -composite resin preheated.	The dual-polymerizing resin-based cement provides lower color stability than the light-polymerizing cement, flowable composite resin, and preheated composite resin.	The mode of polymerization have an impact on the stability of color.
Elkhishen EA et al,2021 (15).	Randomized controlled trial	Investigate the effect of resin cements on the colour stability and translucency of ceramic laminate veneers after cementation and after soaking in coffee solution.	Sixty resin abutments were divided into five groups (n=10): - Group EV: IPS e.max CAD bonded using Variolink Esthetic LC. - Group ER: IPS emax CAD bonded using RelyX Veneer - Group CV: Celtra Duo bonded using Variolink Esthetic LC - Group CR: Celtra Duo bonded using RelyX Veneer - Group KV: Katana Zirconia bonded using Variolink Esthetic LC.	Ceramic laminate veneers bonded with Variolink Esthetic LC resin cement are more translucent. Ceramic laminate veneers bonded with RelyX Veneer resin are more resistant to coffee staining. The lithium disilicate laminate veneer is more resistant to coffee staining than zirconia reinforced lithium silicate and translucent zirconia laminate veneers used for diastema closure.	The resin cement influence the colour and translucency of ceramic laminate veneers used for diastema closure.

Authors, year	Study design	Objectives	Population	Results	Conclusion
Elter B et al ,2021 (16).	Longitudinal study	Investigate the impact of the resin cement and ceramic material on the color stability of sectional laminate veneers	80 sectional laminates veneers were prepared with a thickness of 0.2–0.4 mm from: - IPS e.max CAD - Lava Ultimate - CEREC Blocs - IPS InLine 2 resin cements were used (Variolink Veneer and Variolink N)	Highest marginal discoloration was observed in resin nano ceramic material, The highest colour stability was observed on leucite reinforced feldspathic ceramics.	The type/composition of the material has an effect on color stability of ceramic veneers . Leucite reinforced feldspathic ceramics are recommended for sectional ceramic veneers.
Silami FD et al , 2016(17).	Randomized controlled trial	Investigate of the influence of the thickness of ceramic laminate veneers on the colour stability of the final restoration.	The occlusal surfaces of 80 healthy human molars were flattened. Ceramic laminate veneers (IPS e-max Ceram) of two thicknesses (0.5 and 1.0 mm) were bonded with three types of luting agents: light-cured, conventional dual and self-adhesive dual cement. Teeth without restorations and cement samples (0.5 mm) were used as control.	Colour changes in ceramic veneers is directly related to colour changes on luminosity of resin cement and the thickness of the restoration.	The thinner the restoration thickness , the greater the changes when conventional dual and light-cured cements are used. When self-adhesive cement is used, the alterations do not depend on the restoration thickness.

Authors, year	Study design	Objectives	Population	Results	Conclusion
Hoorizad M et al , 2021.(1).	Randomized controlled trial	Compare the colour variations of two resin cements and their visibility through the ceramic veneers after accelerated artificial aging.	Colour variations (ΔE) was measured using spectrophotometer in the following groups ($n = 10$), before and after accelerated artificial aging: -Group 1, IPS e.max press high translucent ceramic discs. -Groups 2, Variolink NLC resin cement discs. - Group 3, Choice 2 resin cement discs -Groups 4, Variolink NLC discs bonded to e.max ceramic discs. -Group 5, Choice 2 disc bonded to e.max ceramic discs.	Colour change of light-cure resin cements tested in this study was clinically unacceptable after artificial accelerating agents.	Colour variation occurs, especially at the margins compromising the esthetic outcome of restorations.
Strazzi Sahyon HB et al 2018(18).	Longitudinal study	Evaluate the effects of different modes of photoactivation on the colour stability of ceramic laminate veneers.	44 lithium disilicate blocks (7×8×0.6 mm) were cemented onto bovine enamel. They were divided into 4 groups according to the polymerization light used and the mode of activation of the dental adhesive (no previous photoactivation or previous photoactivation).	Previous activation of the dental adhesive in the dental enamel with the Valo polywave polymerization light yielded more color stability.	Previous photoactivation of dental adhesive is recommended for obtain color stability.

Authors, year	Study design	Objectives	Population	Results	Conclusion
Castellanos M et al 2019(19).	Comparative study	Evaluate effect of light-curing resin cements containing different photoinitiator systems on degree of conversion, color stability, and dentin bond strength.	80 Disk-shaped lithium disilicate ceramic specimens that were 0.4, 0.7, and 1.5 mm in thickness were prepared using IPS e.max Press (Ivoclar Vivadent, shade LT/A2). Experimental resin cements were fabricated containing camphorquinone and amine (CQ-amine), TPO, Ivocerin (IVO), or TPO and Ivocerin (TPO-IVO).	Compared to the amine-free cements, CQ-amine cements showed the highest colour changes.	The resin cements combining Ivocerin and phosphine oxide (TPO) TPO showed greater color stability when compared to resin cements containing camphorquinone.
Pissaia JF et al 2019 (20).	Longitudinal study	Evaluate of the influence of curing mode and shade of resin cements on the color stability of minimum-thickness ceramic veneers after a three-year.	96 0.5-mm-thick, feldspathic ceramic veneers (Mark II) were luted on to resin composite substrates (Filtek Z350 XT, shade A2E) with two light-cured (NX3 Light-cure and AllCem Veneer) and dual-cured resin cements (NX3 dual-cure and AllCem) in various shades.	After 2 years of follow up, all cements present acceptable results: - For dual cured cements, NX3 cement presented better colour stability than did AllCem - Light cured resin showed less colour changes than dual cured cements.	Activation mode, the resin cement and time influence the color stability of bonded thin ceramic veneers.
Tuncdemir MT et al 2020(21).	Comparative study	Determine the effects of preparation vs nonpreparation of tooth surfaces and the types of porcelain laminate	40 extracted maxillary central incisors were used. They were divided into four groups:	Preparation of veneers caused more colour changes in PLVs than no preparation.	The amount of preparation and the type of porcelain have impact on colour change in porcelain laminate veneers.

		veneers (PLVs) on color changes after 300 hours of artificially accelerated aging.	<p>Group A: tooth preparation with IPS e.max computer-assisted design (CAD),</p> <p>Group B: tooth preparation with IPS e.max press,</p> <p>Group C: no preparation with IPS e.max CAD,</p> <p>Group D: no preparation with IPS e.max press.</p>		Preparation caused more colour changes than non-preparation.
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4.3. Level of evidence, grade of recommendation and quality assessment

The selected studies were evaluated according to the recommendation grading of the effective public health practice project (EPHPP) quality assessment tool (5) (Table 4) (Table 5).

Table 4. Level of evidence of the included studies and grade of recommendation

Author, year	Type of study	Level of evidence	Grade of recommendation
Khalap SD et al,2021 (6)	Randomized controlled trial	1	A
Bagis B et al ,2013 (7)	Comparative study	3	C
Karaokutan I et al , 2023 (8)	Randomized controlled trial	1	A
Magalhães AP et al ,2014 (9)	Randomized Clinical trial	1	A
Qaraghuli AM et al ,2022 (10)	Randomized controlled trial	1	A
Kilinc H et al ,2017 (11)	Comparative study	3	C
Marchionatti AME et al, 2017 (12)	Controlled randomized Clinical trial	1	A
Gugelmin BP et al 2020 (13)	Prospective Clinical trial	1	A
Lee SM et al ,2018 (14)	Longitudinal study)	4	C
Almeida JR et al,2015 (2)	Longitudinal study	4	C
Elkhishen EA et al,2021 (15)	Randomized controlled trial	1	A
Elter B et al ,2021 (16)	Longitudinal study	3	C
Silami FD et ak , 2016(17)	Randomized controlled trial	1	A
Hoorizad M et al , 2021.(1)	Randomized controlled trial	1	A
Strazzi Sahyon HB et al 2018(18)	Longitudinal study	4	C
Castellanos M et al 2019(19)	Comparative study	3	C
Pissaia JF et al ,2019(20)	Longitudinal study	4	C
Tuncdemir MT et al 2020(21)	Comparative study	3	C

Table 5. Quality assessment of the included studies

Article	Selection biases	Study design	Confounders	Blinding	Data collection methods	Withdrawals and drop-outs	Global rating
Khalap SD et al,2021 (6)	Moderate	Strong	Moderate	Moderate	Strong	Strong	STRONG
Bagis B et al ,2013(7)	Strong	Moderate	Strong	Moderate	Strong	Strong	STRONG
Karaokutan I et al , 2023 (8)	Moderate	Strong	Moderate	Moderate	Strong	Strong	STRONG
Magalhães AP et al ,2014(9)	Strong	Strong	Strong	Strong	Strong	Strong	STRONG
Qaraghuli AM et al ,2022 (10)	Strong	Strong	Strong	Moderate	Strong	Strong	STRONG
Kilinc H et al ,2017 (11)	Moderate	Moderate	Strong	Moderate	Strong	Strong	MODERATE
Marchionatti AME et al, 2017 (12)	Strong	Strong	Strong	Strong	Strong	Strong	STRONG
Gugelmin BP et al 2020(13)	Strong	Strong	Strong	Moderate	Strong	Strong	STRONG
Lee SM et al ,2018 (14)	Strong	Moderate	Weak	Not applicable N/A	Strong	Strong	MODERATE
Almeida JR et al,2015(2)	Strong	Moderate	Weak	Not applicable N/A	Strong	Strong	MODERATE
Elkhishen EA et al,2021 (15)	Strong	Strong	Strong	Moderate	Strong	Strong	STRONG
Elter B et al ,2021 (17)	Strong	Moderate	Weak	Not applicable N/A	strong	strong	MODERATE
Silami FD et ak , 2016(17)	Strong	Moderate	Strong	Moderate	Strong	Strong	STRONG
Hoorizad M et al , 2021.(1)	Strong	Moderate	Strong	Moderate	Strong	Strong	STRONG
Strazzi Sahyon HB et al 2018(18)	Moderate	Moderate	Strong	Moderate	Strong	Strong	MODERATE

Castellanos M et al 2019(19)	Strong	Moderate	Strong	Moderate	Strong	Strong	STRONG
Pissaia JF et al 2019 (20)	Weak	Moderate	Strong	Not applicable N/A	Strong	Weak	WEAK
Tuncdemir MT et al 2020(21)	Moderate	Weak	Strong	Strong	Strong	Strong	MODERATE

5. Discussion

Colour stability is essential to ensure long-term aesthetic success with Porcelain laminate veneers. Previous studies have shown that it is difficult to find clinical evidence on this issue.

It has been the subject of many experimental investigations. In this context, accelerated aging systems have been used for the assessment (22).

These systems imitate oral conditions by exposing the materials to ultraviolet light, heat, continuous humidity, and variations in temperature to accelerate their degradation. According to Bagis and Turgut, an aging cycle of 150 kJ/m² is equivalent to a year of exposure to oral conditions (7).

Colour changes of ceramics veneers can be caused by intrinsic and/or extrinsic factors which compromises the aesthetic outcomes (7).

Intrinsic factors include essentially the composition and properties of resin cement, the polymerization mode, thickness and composition of the ceramic, and the necessity or not for previous photo activation of adhesive resin (1,2).

Meanwhile, extrinsic factors are mainly due to staining by absorption of colorants from exogenous sources, such as beverages, coffee, tea, red wine, smoking nicotine, and mouth rinses (10).

According to Magalhães AP et al, efficient polymerization and a high level of polymer conversion is a key of success colour stability (9).

They explain that residual monomers existing in the polymeric chain can lead to colorimetric degradation products (residual amines and unreacted carbon-carbon bonds).

In addition, it stimulates the penetration of solvents from the oral environment into the polymeric network, thus promoting hydrolytic degradation of the newly formed chain.

They concluded that since there were no significant clinical differences between dual- and light-cured modes when they are submitted to aging, we should focus on the degree of conversion of material rather than the mode of polymerization (9).

The same fact was confirmed by Marchionatti et al, who found on their study, that the results were similar for both light and dual polymerizing mode.

They reported that marginal discoloration increased over a 2-year period for both the light- and the dual-polymerizing modes (12).

Castellanos et al confirmed, by using four photopolymerizing experimental resin cements with different photo-initiator systems containing camphorquinone and amine (CQ-amine), TPO, Ivocerin (IVO), or TPO and Ivocerin (TPO-IVO) CQ-amine cements showed the highest colour changes compared to the amine-free cements (19).

It suggests that the long-term stability of the colour is influenced by both the resin's composition and the photo-initiator system.

They combined resin cements with another factor which is the thickness of the ceramic material. They studied its influence on the degree of conversion and as a consequence on the stability of aesthetic result.

This indicates that the degree of conversion is more significant than the choice between the dual and light modes of polymerization: A higher degree of conversion translates to better mechanical properties (strength, wear resistance), improved marginal integrity (better adhesion to tooth structure), stable optical properties and reduced risk of postoperative sensitivity. Therefore, focusing on achieving a high degree of conversion, regardless of the cure mode, is more crucial for a successful restoration (19).

Almeida et al studied the type of resin-based luting agent. According to them, it might influence the colour stability of ceramic veneers (2).

Additionally, they came to the conclusion that the dual-polymerizing resin-based cement had higher colour variation than light-polymerizing cement.

The prevailing consensus that light-polymerizing luting agents exhibit superior colour long-term stability compared to dual-polymerizing resin cements is supported by these data (4).

This conclusion may not be consistent with earlier research by Marchionatti et al and Magalhães AP et al, but this can be related to photo-initiator included in the material used in the study of Almeida JR et al.

Other experimental studies, which tried to imitate the clinical conditions, reported that dual resin cements have more aptitude to colour change, while higher colour stability is associated with light polymerization. This may be because of their aliphatic amines, which present low potential to oxidation (20) (3).

For all of these reasons, the clinician needs to be aware of the photoinitiator system when using light mode (7).

Elkhishen EA et al. claim that the choice of resin material affects the degree of translucency of ceramic laminate veneers, which in turn affects the ceramic veneers' long-term success (15).

According to their study, Ceramic laminate veneers bonded with RelyX Veneer resin are more resistant to coffee staining than Ceramic laminate veneers bonded with Variolink Esthetic LC resin. This discrepancy can be related to the difference of the photo-initiator present in the material.

They also concluded that the lithium disilicate laminate veneer is more resistant to coffee staining than zirconia reinforced lithium silicate and translucent zirconia laminate veneers. As consequence, lithium disilicate is highly recommended for ceramic veneers. (15).

To evaluate the influence of antioxidant agents on the optical and mechanical properties of the bonding interface components after dental bleaching in ceramic laminate veneer luting., Strazzi Sahyon HB et al conducted a comparative study on population of 143 bovine teeth (18).

According to this study, the use of the α -tocopherol antioxidant solution after the bleaching process for 24 hours did not affect the optical properties of the adhesive interface of the laminate restorations compared to those of the control group. So, it has been concluded that a 10% α -tocopherol antioxidant solution could be mediately used after tooth bleaching and before luting ceramic veneers (18).

A key aspect considered to be essential to the long-term success of these minimally invasive restorations is the adhesive cementation process.

For this reason, we have to focus on whether or not we need to photoactivate the adhesive before. It was Strazzi Sahyon HB et al who conducted the research on this issue, concluding that to obtain color stability, the dental adhesive must first be photoactivated. (18).

Regarding the influence of material selection for ceramic veneers on colour stability, Elter Bet al worked on a population of 80 sectional laminates veneers were prepared with a thickness of 0.2 0.4 mm from: (IPS e.max CAD-Lava Ultimate- CEREC Blocs - IPS InLine) (16).

They concluded that there is a direct relation between the type/composition of the restorative material and the long-term colour stability of ceramic veneers.

They also recommended leucite reinforced feldspathic ceramics for sectional ceramic veneers. Overall, leucite-reinforced feldspathic ceramics offer a good balance of strength, aesthetics, and colour stability, making them an optimal choice for sectional ceramic veneers (16).

According to a 2013 longitudinal study by Lee SM et al, highly-translucent lithium disilicate glass ceramic is more susceptible to colour changes. Furthermore, they suggested using transparent resin cement to luting highly translucent ceramics since resin cement's lower brightness increases greater colour stability (14).

In essence, using a highly translucent ceramic offers aesthetic benefits but requires careful consideration of potential colour shifts. Transparent cement helps mitigate this issue and achieve a more predictable and stable final colour for the restoration.

Karaokutan I et al conducted a similar investigation and found that colour variations were detected in all laminate veneers after artificial accelerated aging.

The authors reported that zirconia-reinforced lithium disilicate veneers present similar colour changes as lithium disilicate veneers (8).

This discrepancy in results may be related to experimental conditions and difficulty for simulating oral environment.

On the other hand, previous studies conducted by D'Arcangelo C et al, Rabia Arif et al and G Gurel et al found an association between marginal adaptation and marginal discoloration, and that these could be the earliest clinical signs of veneers deterioration (23) (24) (25).

In fact, a decrease in marginal adaptation was associated with an increase in marginal discoloration. Thus, authors highlighted the importance of the quality of the preparation, cementation, and the adoption of a finishing procedure, which all contribute to a better quality of marginal restoration.

These findings results were also reported by Tuncdemir MT et al., who focused on the impact of preparation amount on colour variation in porcelain laminate veneers in their comparative investigation. Compared to laminate veneers without preparation, they observed a higher degree of colour changes when porcelain laminate veneers were bonded on prepared teeth (21).

The amount of tooth preparation is correlated with thickness of the veneer.

This was explained by Silami FD et al., who found that colour variations in ceramic veneers are directly related to the thickness of the restoration and to colour changes on the luminosity of resin cement: the thinner the restoration, the greater the colour variation (17).

These conclusions are in accordance with the study conducted by Hoorizad M et al, who reported that discoloration occurs especially at the margins with a compromise on the aesthetic outcome (1).

Regarding the extrinsic factors that may affect colour stability, Qiaraghuli AM et al. observed that staining beverages that patients commonly consume are affecting the colour stability of ceramic veneers (10).

Several ceramic materials, including feldspathic ceramic, hybrid ceramic, zirconia-reinforced lithium silicate glass ceramic, and composite resin, were subjected to staining agents found in commonly drunk beverages. They concluded that staining common beverages significantly alters the colour of the tested restorative materials.

On the other hand, hybrid ceramics can be a good alternative for laminate veneer restoration with a clinically acceptable colour variation. Composite resins had the highest colour change among other tested aesthetic restorative materials, and their discoloration by staining agents was visually perceptible as well as clinically unacceptable (10).

60% of the studies included in this systematic review have received strong rating for quality assessment, which denotes a low risk of bias. However, a limitation of this review is the fact that the literature research was conducted in only one database. In order to more deeply investigate the factors that impact color stability of ceramic veneers, more randomized controlled clinical trials are needed, in particular with a longer follow-up period.

6. Conclusion

The current systematic review has highlighted many factors affecting the long-term aesthetic durability of ceramic veneers.

- The degree of conversion and polymerization efficiency are more significant than the choice between the dual and light modes of polymerization. The photoinitiator system is a factor a clinician needs to be aware of while using light mode.
- It is advised to photoactivate dental adhesive beforehand to achieve colour stability.
- A 10% α -tocopherol antioxidant solution could be mediately used after tooth bleaching to lute ceramic laminate veneers.
- The optical properties and colour stability of ceramic veneers are influenced by the resin cement's composition. When compared to resin cements containing camphroquinone, the resin cements combining Ivocerin and TPO demonstrated increased colour stability.
- Colour variation occurs especially at the margins.
- leucite reinforced feldspathic ceramics are recommended for sectional ceramic veneers and manual polishing or glazing is highly recommended.

Regarding the extrinsic factors; Staining beverages frequently consumed by patients negatively compromise the colour stability of ceramic veneers. So, they should be avoided as possible after luting of the restorations.

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