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Survey of Porcelain Laminate Veneers

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

Gandra, 15 de Junho de 2020

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Trabalho realizado sob a Orientação do Prof Doutor Carlos Manuel Aroso Ribeiro

Declaração de Integridade

Kuppuswamy Niranjankumar, estudante do Mestrado Integrado em Medicina Dentária do Instituto Universitário de Ciências da Saúde, declaro ter atuado com absoluta integridade na elaboração desta Dissertação.

Confirmo que em todo o trabalho conducente à sua elaboração não recorri a qualquer forma de falsificação de resultados ou à prática de plágio. Mais declaro que todas as frases que retirei de trabalhos anteriores pertencentes a outros autores foram referenciadas ou redigidas com novas palavras, tendo neste caso colocado a citação da fonte bibliográfica.

Declaração

Eu, "Carlos Manuel Aroso Ribeiro", com a categoria profissional de "Professor" do Instituto Universitário de Ciências da Saúde, tendo assumido o papel de Orientador da Dissertação intitulada *"Survey of Porcelain Laminate Veneers"*, do aluno do Mestrado Integrado em Medicina Dentária, "Kuppuswamy Niranjankumar", declaro que sou de parecer favorável para que a Dissertação possa ser presente ao Júri para Admissão a provas conducentes à obtenção do Grau de Mestre.

Gandra, 15 de Junho de 2020

O Orientador

Agradecimentos

A Deus, que tem sido a força motriz durante minha vida e ilumina meus caminhos.

Este trabalho é dedicado aos meus pais, especialmente à minha mãe. Depois da morte de meu pai no fim dos anos 80, conseguiu educar-me e aos meus irmãos. Sem os seus sacrifícios não estaria neste mundo. Infelizmente ela já não está connosco, mas estará sempre no meu coração a dar forças para que eu supere todas as batalhas na minha vida.

Aos meus irmãos e à minha irmã que sempre me guiaram durante os meus estudos e carreira.

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Resumo

O propósito desta revisão da literatura é conduzir uma revisão sobre as facetas laminadas de porcelana: visão geral, materiais cerâmicos, preparação dos dentes para as facetas, cementação e tecnologias informáticas tais como desenho assistido por computador e fabrico assistido por computador. E, assim, produzir dentes próximos dos naturais que contribuam para a melhoria estética e autoconfiança do paciente.

Os desenvolvimentos de materiais e tecnologias restauradores proporcionaram a produção de dentes estéticos com reduzida perda estrutural de tecido duro. As facetas de porcelana são usadas como tratamento eficaz, pois produzem dentes funcionais e quase naturais com estética e funcionalidade excelentes, melhorando a estética e a autoconfiança do paciente. São uma opção de tratamento minimamente invasivo para os dentes anteriores, com uma perda mínima da sua estrutura.

As facetas de porcelana têm revelado sucesso clínico a longo prazo. Têm demonstrado ser um dos tratamentos com mais sucesso em odontologia, na restauração da estética e funcionalidade dos dentes anteriores. Uma abordagem minimamente invasiva, material cerâmico biocompatível, durabilidade de adesivo, fiabilidade e resistência tornaram estas facetas num tratamento de confiança para os dentistas. São as que melhor cumprem os princípios da odontologia estética contemporânea. Têm sido indicadas para situações clínicas com uma boa taxa de sobrevivência. Os mais recentes desenvolvimentos de sistemas de design e produção por computador permitem a produção de facetas de porcelana mais vantajosas e de melhor estética, com uma elevada taxa de sucesso.

A pesquisa de literatura foi feita no PUbMed usando as palavras-chave: Facetas; Porcelana Dentária; Porcelana laminada; Desenho assistido por computadores; Restaurações estéticas e dos 240 artigos identificados, 29 foram relevantes para este trabalho.

Palavras-Chave

Facetas; Porcelana Dentária; Porcelana laminada; Desenho assistido por computadores; Restaurações estéticas

Abstract

In this literature work we conduct a systematic review on porcelain laminate veneers (PLVs). We discuss its usage, especially materials used, tooth preparation methods, cementation, and computer technologies such as computer aided designing and manufacturing for production (CAD-CAM).

Latest developments in restorative materials and techniques have allowed production of more aesthetic teeth with minimum structural loss of hard tissue. PLVs are used as an effective treatment option as they produce close-to natural and functional teeth with excellent aesthetic and function and improves aesthetics and self-confidence of the patient. They are a minimally invasive treatment option for anterior teeth with minimum loss of tooth structure.

PLVs have shown long-term clinical success. It has proved to be one of the most successful treatment options available in dentistry to restore the aesthetics and function of the anterior teeth. A minimally invasive approach, biocompatible ceramics, bonding durability, reliability and improved strength made veneers a reliable treatment for dentists. Porcelain veneers best comply with the principles of the modern-day dentistry aesthetics. They have been indicated for many clinical situations with good survival rate. The recent development of CAD-CAM allow production of more favorable and aesthetically improved PLVs with high success rate.

The literature search was performed in PubMed using key words: Veneers; Dental porcelain; Porcelain laminate; Computer aided design; Aesthetic restorations and identified 240 articles of which 29 were relevant to this review.

Keywords

Veneers; Dental porcelain; Porcelain laminate; Computer-aided design; Aesthetic restorations.

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Abbreviations

2D – Two dimensional

3D – Three dimensional

APT – Aesthetic Pre-Evaluative Temporary

CAD – Computer Aided Design

CAM – Computer Aided Manufacturing

FV – Full veneer

HF – Hydrofluoric Acid

OV – Overlap

PLV – Porcelain Laminate Veneer

1 Introduction

Dental clinicians aim to deliver optimal aesthetics which is a core requirement of patients. In the last three decades, the area of restorative dentistry has substantially undergone developments to achieve better aesthetics and function, with minimum removal of dental hard tissues. This revolution was enhanced by introduction of high-quality dental materials such as ceramics, composite cements, and etching and bonding techniques (1).

One way to achieve this aim is by usage of direct or indirect composite veneers and full crowns. The full coverage crowns require aggressive dental hard tissue preparation, which have a side effect on pulpal and periodontal tissues. Crowns are typically bonded with composites and easily get discolored and become more fragile. Alternative solutions led to the development of PLVs. PLVs are also known as contact lens of the tooth (they have a thickness around 0.3-0.5mm) and are a minimal conservative treatment aimed at restoring aesthetics and function of anterior teeth (1–4).

PLVs are intended to cover the buccal surface of the tooth with a ceramic substitute, closely adhered to the tooth surface. They aim to produce optical mechanical properties and biological elements that closely resemble tooth enamel. Hence, they create a natural biomimicry that restores facial aesthetics, function and harmony (5–9).

PLVs are mainly made of feldspar that contains silica, oxides (aluminium, sodium, potassium, boric), and crystals. Due to its natural appearance, it can be used as an alternative to other veneers in restorative dentistry. It is currently seen as an excellent treatment option versus other techniques which requires more preparation (4).

Ceramics gives better adhesion to enamel and have the characteristics of biocompatibility, colour stability, thermal expansion, optical translucency that are similar to enamel. These properties increase the survival outcome of the treatment (9-11).

The development of new ceramics such as leucite reinforced with feldspar, oxide ceramics and Zirconia are seeming to be modern day materials with high strength and durability (7, 11, 12).

PLVs can be used in several clinical situations such as discolouration, closure of diastema, developmental defects, malposition, incisal fracture and enamel alterations. PLV technique is a compromise between bleaching and full crown (1, 5, 7, 12)

Initially, veneers were used to treat minor cases, but the development of advanced materials and techniques has elevated their potential usage and have become a probable and realistic option that is a minimally invasive approach due to minimum or no preparation at all (1,3, 5).

The demand for aesthetic, functional and durable PLVs resulted in the improvement of new materials and preparation designs. New preparation techniques were introduced to restorative dentistry to fulfil the production of aesthetically successful veneers. The recent development of a tooth preparation guide such as "FirstFit®" allows tooth reduction control accurately; this allows preparation of highly successful PLVs (3).

This method further enhanced by introducing new technologies like "CAD-CAM" enables to make veneers with high speed and easy. The PLVs produced with this technology have natural appearances and optical translucency that mimic dental enamel (3, 13, 14).

CAD-CAM allows the production of veneers that mimic natural dentition and involves copying the necessary colour, contour, and shape through a milling machine, producing veneers faster, more durable with a high predicted survival rate. In addition, digital planning software is a valuable aid in achieving the desired outcome and also allows to discuss the pretreatment plan with the patient and to show the approximate results to avoid any future failures. By using CAD-CAM technology it is possible to produce veneers in a single visit without any traditional impression (13, 14, 16).

2 Objective

The objective of this work is to carry out an integrative systematic review on the use of Porcelain laminate veneer in anterior teeth and its survey.

3 Materials and methods

The literature survey was performed in PubMed database platform. The publication year range was from 2010 to 2019 and papers were in English.

The research was conducted by using combinations of keywords used as: Veneers; Dental porcelain; Porcelain laminate; Computer Aided Design; Aesthetic Restorations using the search "strings" as "Or" or "And".

Our search criteria included the overview of ceramics, PLVs, indications and contra indications of PLVs and as well as advantages and disadvantages of the same. Furthermore, we collated results on computer technology systems, specifically CAD-CAM, its usage in PLVs production and its, advantages and disadvantages.

Some other articles were also included in this review due to their relevance and importance to our work.

The selected and relevant articles for inclusion for this article review was required a detailed search analysing the titles, and abstracts of potentially relevant articles. The articles found the following objectives systematic literature review, clinical retrospective and prospective review, clinical investigational studies, and case studies, literature review also include textbook references.

All the articles were objected towards the combination of key words and duplicate articles were removed by using Mendeley citation manager.

In (Attachment A) we the present the objective, mechanism of study, intervention, and results of all selected publications.

4 Results

The following is a summary of our review of PLVs which showed the close results for our inclusion criteria.

The literature search from the PubMed database identified a total number of 240 articles (**Figure 1**).

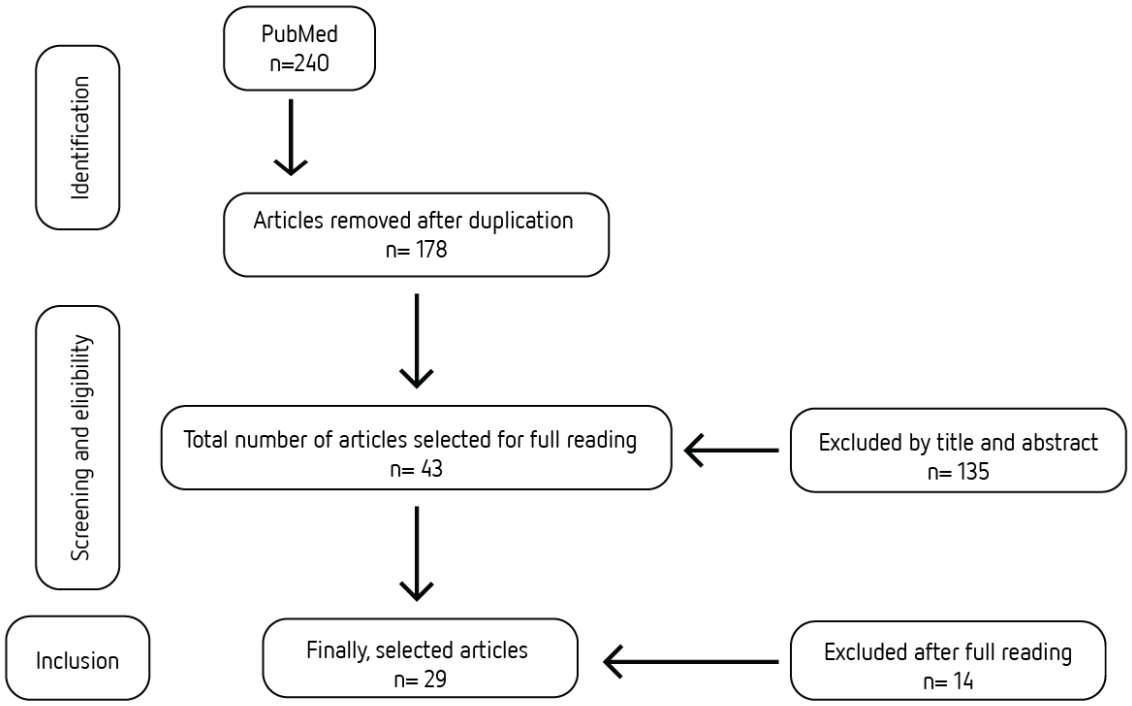


Figure 1. Flow diagram - Total number of articles identified through PubMed database.

After removing the duplicates, 135 articles were deselected after reading the abstract and title which did not meet our inclusion criteria as shown in the table. The remaining 43 potentially relevant articles were studied, out of those articles, 14 were excluded because they did not provide any comprehensive data considering the purpose of the present literature review. Thus 29 articles were included in this review (**Table 1**).

Table 1. Relevant data gathered from the retrieved studies.

	Title of the Article	Author & Year	Mechanism of Study	Objective	Results
1	Survival rate of all-ceramic restorations after a minimum follow-up of five years	Nara Santos et al., (2016)	Systematic literature review.	To study the 5 years complication and survival rate of ceramic restorations.	If the right clinical procedures are taken care that PLVs have 5 years survival rate.
2	Prospective clinical study of press-ceramic overlap and full veneer restorations-7 years results	Guess Petra et al., (2014)	Clinical-Prospective study.	To study the outcome of overlap and full veneer prepared PLVS.	The study showed FV -100% mean time 97,6% OV during the 7 years of time.
3	Clinical Performance of Porcelain Laminate Veneers for Up to 20 Years.	Beier, Ulrike Year., (2012)	Clinical-Prospective study.	To study the success and quality of front veneers made out of glass ceramic has analyzed for 20 years.	93.5% Survival rate of 10 years. Main failure reason were-fracture, bruxism and nonvital abutment teeth. Endodontically treated and smokers found marginal discoloration and no difference in maxilla and mandible.
4	The Up to 21-Year Clinical Outcome and Survival of Feldspathic Porcelain Veneers.	Layton et al., (2012)	Clinical investigational study.	Outcome of feldspathic veneers up to 21 years.	Feldspathic Veneers survival rate is 21 years cemented to minimally prepared surface-96% with high survival and less failure rate.
5	Minimally invasive laminate veneers: clinical aspects in treatment planning and cementation procedures.	Morita, RK et al., (2016)	Clinical-Prospective study.	Conservative approach in anterior teeth restorations and to find about functional and aesthetic rehabilitation with veneers.	Clinical protocols such as selection of ceramics, etching, bonding is carried out carefully PLVs are ideal and minimally invasive option for aesthetic anterior teeth.
6	The effect of HF etching duration on the surface micromorphology, roughness, and wettability of dental ceramics.	Ramakrishnaiah et al., (2016)	Investigation study.	Evaluate time effect of HF etching in different kind ceramics.	HF etch makes difference in the ceramic surface and maximizes structure of ceramic thus enhancing bonding capacity. Time is an important factor for acid etch with HF.
7	Advances in dental veneers: materials, applications, and techniques.	Pini et al., (2012)	Systematic literature review.	Discuss PLV materials, applications, techniques, indication and contraindications, advantages, and disadvantages.	Ceramic is similar to dental tissue due to its mechanical ability. PLVs success is depend on right choice of materials.

8	Porcelain veneers: An update.	El-Mowafy et al., (2018)	Systematic literature review.	Objective to discuss about the PLVs materials, applications, techniques, preparation methods, indication and contraindications, advantages, and disadvantages.	PLVs seems to be an alternative treatment option in anterior teeth rehabilitation. This is achieved by proper selection of ceramics, tooth preparation, cementation thus give a high survival rate.
9	Ceramic materials in dentistry: historical evolution and current practice.	Kelly, J Robert 2011	Systematic literature review.	Dental ceramics and its development, history, chemical components, indication, and its usage in dentistry.	Ceramics have high advantage such as mimic natural like enamel, biocompatibility, and good bonding. Mostly are glass filled and main filler is leucite which is used in low concentration in metal ceramics and high in all ceramics.
10	Feldspathic veneers: what are their indications?	McLaren, Edward et al., (2011)	Systematic literature review.	Verify characteristics of the material, preparation, indications, and case studies.	High aesthetic properties with less tooth preparation feldspathic ceramic simplifies the production of PLVs
11	Five-year clinical outcomes and survival of chairside CAD/CAM ceramic laminate veneers - a retrospective study.	Farahnaz Nejatidanes et al., (2018)	Clinical retrospective study.	To compare the survival, and periodontal parameters of PLVs made with Empress Emax CAD CAM	Chair-side CAD-CAM PLVs had a survival rate of 99% and 96,4% in 5 years' time.
12	Survival rates for porcelain laminate veneers with special reference to the effect of preparation in dentin: a literature review.	Burke FJ., (2012)	Systematic Literature review.	To look for survival rate of PLVs if the preparation is not confined to enamel but extended to dentin.	100% survival rate is rare, and the preparation was made in the dentin effect the success rate.
13	Minimum thickness anterior porcelain restorations.	Radz GM., 2011	Systematic Literature review.	To find the latest Porcelain materials in usage of PLVs	Success of PLVs depends on the right selection of patient and evaluating the indication and contraindications, tooth preparation gives a high success rate.
14	The Current State of Chairside Digital Dentistry and Materials.	Markus B. Blatz., (Year 2019)	Systematic literature review.	Brief of current state of CAD-CAM technology and materials.	CAD-CAM is being used and this has become user friendly, effective, more accurate compare to traditional PLV methods. Recent development of intraoral cameras, sophisticated software's which allows to produce more natural teeth. Modern materials simplify to make PLVs in one visit

					without any traditional impression by not having to fix the temporary restorations.
15	A digital guiding device to facilitate cementation of porcelain laminate veneers.	Xi Chen.et al., (2019)	Clinical Retrospective study.	Presents a CAD-CAM guiding device to facilitate the simultaneous preconditioning and cementation of multiunit PLVs.	Guiding device produced from PLVs digital case provides accurate etching and cementing.
16	Influence of Enamel Preservation on Failure Rates of Porcelain Laminate Veneers.	Galip Gurel et al., (2013)	Clinical Retrospective study.	To study the clinical parameters and effect on survival rate up to 12 years.	The preparation has to be maintained in enamel. If the extension is into dentin the survival rate is decreased.
17	Establishing a classification system and criteria for veneer preparations.	LeSage B., (2013)	Investigation study.	Overview of advantages of no-reparation and minimal-preparation veneers	Proposed two more classification to enhance the tooth preparation for PLVs. Clinician's communication with patient in relation to pre-treatment plans gives a better result.
18	Esthetic, occlusal, and periodontal rehabilitation of anterior teeth with minimum thickness porcelain laminate veneers.	Da Cunha LF et.al., (2014)	Clinical Retrospective study	Multidisciplinary approach of PLVs application with minimum thickness ceramic veneers.	PLVs are ideal for diastema. High survival rate is achieved when patient is well informed, and selection of ceramics plays a huge role.
19	The use of CAD/CAM in dentistry.	Davidowitz. G et.al., (2011)	Systematic literature review.	History of CAD-CAM, advantages and disadvantages indications and contraindications.	CAD-CAM produced PLVs has high precision and natural tooth appearance.
20	Using CAD/CAM–Modified Correlation Mode to Produce Laminate Veneers:	Siqueira De FSF et.al., (2017)	Clinical Retrospective study.	Multiple CAD-CAM produced PLVs using a new self-etching glass ceramic primer to reduce the cementation time.	The usage of single primer allows to etch and salinize in one time. This is reduced the chairside time errors occurs during the procedure.
21	Laminate veneers: Preplanning and treatment using digital guided tooth preparation.	Bruno Pereira da Silva et.al., (2020)	Clinical Retrospective study.	New digital technology that can be used to focus the challenge showing its advantages and limitations. FirstFit® is a digitally guided tooth preparation system that can be used to control	Guided prep system allows minimally invasive, digitally guided veneer preparation. This reduces the need for provisional restorations. This increases accuracy, efficiency, and predictability by reducing the chair time. Furthermore, guided cementation

				the accurate and efficient preparation of teeth.	plates improve the cementation technique.
22	Effect of Preparation Designs on the Prognosis of Porcelain Laminate Veneers.	Hong N, et.al., 2017	Systematic Literature review.	Relation in between preparation designs and prognosis of PLVs.	Failure risk is high in incisal coverage compare to without the incisal. Overlap is higher than butt joint.
23	Ceramic laminate veneers: clinical procedures with a multidisciplinary approach.	Veneziani M. 2017	Clinical Retrospective study.	To demonstrate a correct clinical protocol to provide PLVs. This was achieved with and multidisciplinary approach by using most recent clinical and scientific evidence.	Importance of diagnostic and therapeutic protocol in delivering the PLVs shown how, by combining different fields of dentistry (hygienic and periodontal therapy, restorative, mucogingival surgery, orthodontic, and prosthetic therapies), an excellent result can be achieved
24	Minimally invasive vertical preparation design for ceramic veneers.	Imburgia M, et al., (2016)	Clinical Research study.	Advantages of feather edge preparation methods in the tooth preparation of PLVs.	The feather edge preparation simplifies the technique to apply the minimum invasive methods.
25	Anterior restorations: The performance of ceramic veneers.	Edelhoff D, (2018)	Systematic literature review.	To study the success of PLVS depend on the team effort and technician to fabricate everlasting PLVs.	A multidisciplinary team approach with proper treatment planning, analysis, tooth preparation, and properly performed bonding and proper occlusal contacts are the foundation for the success of the PLVs.
26	Use of Feldspathic Porcelain Veneers to Improve Smile Harmony: A 3-Year Follow-up Report.	Federizzi L et al., 2016	Clinical Case study.	To improve the shape of the anterior teeth and alignment to reestablish smile using feldspathic ceramics harmony, using feldspathic PLVs.	Feldspathic PLVs are ideal indication to treat the anterior tooth shape.70% of enamel has to be presented to achieve a high success rate.
27	Minimally invasive veneers: current state of the art.	Vanlıoğlu BA et al., (2014)	Systematic literature review.	Important parameters in determining the high survival rate and correct application of PLVs.	Minimal invasive approach is an alternative to other restorative treatment option for anterior teeth restoration. This is further enhanced by ceramics, bonding materials. The survival rate of 75% and 100% from 18 months to 20 years.
28	Retrospective evaluation of the clinical performance and longevity of	Arif R et al., (2018)	Clinical Retrospective study.	To assess the clinical success and longevity of PLVs.	Results were the following fracture rate were higher and the following were in order, porcelain chipping, caries, debonding, crack lines, loss of and

	porcelain laminate veneers 7 to 14 years after cementation.				replaced veneers. There was a high survival probability for the veneers at both 7 (97.6%) and 14 years (88.2%). The failure rate of these veneers was less than 5% over at least 7 and up to 14 years, with porcelain fracture being the main cause.
29	Minimally invasive aesthetic therapy: A case report describing the advantages of a multidisciplinary approach.	Pinto RC et al., (2013)	Clinical Case Study.	Assess the success of PLVs and its durability.	The multidisciplinary approach of treating PLVs has high survival rate.

Out of the 29 articles fourteen articles (48.27%) discussed about ceramics its characters, usage, indications, contraindications, advantages, and disadvantages of PLVs. While five articles (17.24%) reviewed about tooth preparation techniques. Five articles (17.24%) analyzed about of CAD-CAM usage, advantages and disadvantages of the same. Furthermore, three articles discussed about the survival rate (10.34%) and two articles (2%) reviewed about the cementation.

From our literature review the major findings are drawn as follows:

1. The current concept of restorative Dentistry recommends that, for any type of procedure, a dentist should always choose the minimal invasive technique, that preserves the health of dental structure (1, 4, 5, 17-18);
2. PLVs mimic the natural appearance of enamel. They also have bio compatibility and durability. This makes them a great treatment (5, 9, 10);
3. PLVs are good options for substituting for anterior restorations in places where aesthetics and strength are required with minimally invasive techniques (1, 5, 18);
4. The preparation should be in enamel and always must be minimally invasive as possible to obtain a good bonding with ceramics and enamel to improve the aesthetics and function (1, 5, 12, 18);

5. The proper case selection and pre-treatment evaluation of indications and contraindications, advantages and disadvantages has resulted in good survival rate (5, 11, 16, 17);
6. The CAD-CAM system allows to produce PLVs with less time and high-quality aesthetics (3, 14, 20);
7. Overall patients' satisfaction with PLVs were excellent and it is a good treatment option in restorative dentistry (5, 7, 11, 18, 19).

The articles were excluded due to the following exclusion criteria:

- Articles which were written in other languages;
- No clear description of PLVs;
- Articles describing about other types of veneers;
- The articles which not discuss about the indications and contraindications;
- Inadequate information's about PLVs advantages and disadvantages.

5 Discussion

5.1 Survey of PLVs

In this survey section, we discuss PLV's applications and case selection criteria. Next, we will discuss the development of ceramics and PLVs as well as ceramic chemistry and its varieties.

5.2 Overview of PLVs

There are several types of veneers used in dentistry but in this review we focused on PLVs. PLVs, are also known as the 'contact lens' of the tooth, are thin coverings widely used to cover the labial surface of anterior teeth with the aim to achieve an aesthetic solution and protection. Such an application is called laminate because it contains multiple layers of thin sheets (2, 19).

PLVs can be made by various types of material such as direct and indirect composite as well as ceramics; however, they are typically made out of porcelain that is etched with an acid (hydrofluoric) and coated with a material (silane) that is bonded to prepared enamel with a resin base cement (10, 19).

The author Mc Laren claims that PLVs have a long-term durability due to their physical and chemical properties and their composition (feldspar, oxide and crystals). Thus they have strong characteristics and various applications in dentistry (5, 9).

A survey by Santos et al explained the importance of respecting clinical and multidisciplinary approach for laboratory protocols and bonding criteria. If all the steps are followed correctly, great and high survival rate can be achieved (7, 11, 21).

5.3 Applications

PLVs have become more popular because there are many clinical presentations that they can be applied and Radz states the most common application on veneers (1, 3, 5, 10, 16, 18, 22):

- Discoloured teeth or restorations;
- Dental Malformations or malposition;
- Diastemas;

- Crown fractures;
- Erosion and abrasion.

In all these applications, a minimally invasive or no-preparation method should be used to preserve the tooth enamel (1, 5, 7, 25). It is very important to decide the type of approach a dentist will utilize to get a result that is predictable and successful (5).

The further and detailed application of PLVs will be discussed in the PLVs indications section.

5.4 Case selection criteria

The following case selection criteria are used for fixed veneers (1, 5, 25, 27, 28):

1. The patient attitude in maintaining a good oral health and maintenance of veneer;
2. Dynamic and stable occlusion, which this is a basic consideration since chipping and fractures are common in veneers;
3. Maximum care should be taken in the treatment of the incisal edge. It should be placed in a position that should not contact the lower or upper dentition when resting;
4. Gingival architecture should be symmetric;
5. A healthy gingiva and periodontal tissues should be present;
6. A proper study of dental hard tissues which include existing lesions, restorations if any, severity or degree of discolouration, amount of enamel available for bonding defines the type of veneer to be applied;
7. Any pre-existing habits such as nail biting, bruxism must be treated before deciding on PLVs.

5.5 Development of Ceramics and PLVs

5.5.1 Ceramics

The usage of Porcelain in dentistry started in 18th century in China and spread elsewhere from there. It is claimed that Nicholas Dubois de Chémant from Paris was the first European dentist to

make a denture for a patient (26). Dental ceramics were structured for routine fusion into metal substructures which widely increased the usage of ceramics in dentistry (26).

With time, ceramic techniques have undergone tremendous changes to improve its performance. Synthetic glass ceramics were discovered in 1953. This ceramic can be produced by any glass forming technique to use in dentures (9). In the 1960s metallic ceramics were emerged which fused metal and ceramics and included a crystalline phase mainly in leucite which created resistance and aesthetics in the same piece (9).

In the last three decades, due to high demand for aesthetics and strength, ceramics reinforcement became a topic of interest. Some examples being leucite reinforced with glass-lithium disilicate ceramics, glass-lithium silicate, phosphate, and aluminium oxide reinforced ceramics-zirconia ceramics, monolithic zirconia and translucent zirconia,inceram alumina, inceram zirconia, inceram spinell, procera all ceramic (9, 10).

5.5.2 PLVs

Ceramics have commonly been used as a material in restorative dentistry. Its composition and properties made it useful in producing dentures and other appliances. In 1938, Dr. Pincus was the first to introduce anterior tooth veneering for Hollywood film actors, noticeably for movie close ups, by attaching veneers with the usage of denture adhesive powder. This revolution made the entrance of PLVs in restoring the anterior teeth to achieve better esthetics (1, 2, 4, 19, 21).

The art of acid etch technique was invented by Buonocore in 1955 to create micro-porosity. This increased the strength of restorations. The technique was further advanced with the development of silica resin-filling material by Bowen, which made usage of PLVs in restorative dentistry popular (1, 4, 10, 19, 27).

Further this was followed by the use of an acrylic veneering procedure using composites which are currently used as a cement. These acrylic veneers were made indirectly with acrylic and bonded to the acid-etched enamel surface by a light cured composite (1). The first commercially made preformed veneer, called mastique (caulk) was manufactured in 1979. In the long term it has been shown that due to lack of true bonding in between enamel and acrylic more fracture and

unaesthetic veneers occurred (1). The usage of acid-etch methods, composite resins and silane-coupling agents have enabled successful production of PLVs (1, 6, 24).

Calamia and Calmaia also state that the introduction of acid etch and silane conditioning techniques was of great importance in achieving a satisfactory result with. Silane technique increases the adhesion of PLVs to enamel surface for resin materials to improve the strength of the restoration (27, 28).

The preservation of enamel and the minimally-invasive approach was a key factor for the success of PLVs that was previously overlooked, or was of little concern, and generated recurrent cases of fractures and caries (1).

In the beginning, PLVs application did not have their teeth prepared and the thickness of the porcelain was around 0.5 mm thick. This size is very different from what is currently practised where the thickness is normally 0.3mm at a minimum (5, 6, 12, 18). This modern approach has become as an alternative method to crowns, which requires nearly three times more tooth preparation (1).

With the development of new ceramic materials and techniques there was an increase in the PLV's durability rate. According to Radz, the success rate of the PLVs are 94% in 10 years which is considered to be very high when compared to other techniques. However, it should be noted that each patient has to be treated with a personalised protocol to maintain the minimally invasive-technique (1, 11, 19).

5.6 Ceramics chemistry and varieties

In this section we will elaborate on the ceramic properties and its varieties which are used in restorative dentistry. It is beyond the scope of this work to create a full classification of ceramics in restorative dentistry due to new development of compositions and improvements of materials, but we present here an abbreviated overview.

There has been a growing interest in the use of ceramics in restorative dentistry. This is purely due to the following properties (2, 9, 18, 25, 28):

- Biocompatibility;
- Resistance to abrasion;
- Adequate translucency;
- Colour;
- Contour stability.

Ceramic is an inorganic compound mixed with non-metallic properties and typically composed of metallic and semi-metallic elements.

According to Kelly & Benetti, there are 3 basic classes of dental ceramic materials (26):

1. Predominantly glass - this best mimics the aesthetic properties of the teeth;
2. Particle-filled glass - this is added to base glass to improve mechanical strength and optical effects;
3. Poly crystalline ceramic - this is tougher and stronger than glassy ceramics.

A common material used to fabricate restorations is feldspathic porcelain and belongs to the first category of predominantly glass (4, 26).

Initially feldspathic ceramics were used for dentures, but later were also included as an alternative material for PLVs once their advantages were realised (9).

The basic composition of feldspathic porcelain is feldspar, a naturally occurring glass which contains silicon, aluminium, and potassium oxide (5). Feldspathic PLVs have many advantages. It is a very thin material, so it is almost translucent. This property encourages results appearance similar to natural tooth (9, 19). They have also been found to be long lasting (9).

However, it is important to point out that this material needs attention when optimal mechanical strength is required. Feldspathic PLVs have low flexural strength and are easily fractured (10, 26).

There are many techniques to manufacture feldspar PLV (10):

- Conventionally;

- Casting technique;
- Heat pressing technique;
- Infiltrated with other substances to reinforce the strength;
- CAD-CAM.

An alternative to feldspar is filler infiltrated in to glass matrix to obtain high strength, which reduces the chances for internal defects such as lithium dioxide reinforced, leucite reinforced (1, 10).

Feldspathic and glass ceramics are most commonly used for veneer production. Recently, many new ceramic systems have been manufactured to improve the strength and optical properties. They include properties such as ultra-thin profile, better aesthetics, long life span and maximum bonding strength.

Some of these ceramics include (5):

- With reinforced leucite;
- Lithium disilicate;
- Lithium silicate phosphate;
- Zirconia;
- Monolithic Zirconia;
- Translucent Zirconia.

5.7 Clinical Steps in PLVs

The success of PLVs is dependent on the following clinical steps (5, 11, 25, 27):

1. Proper case selection and treatment planning;
2. Tooth preparation;
3. Impression (conventional-digital);
4. Provisional restorations;

5. Laboratory procedures;
6. Placement, polishing and finishing;
7. Post clinical follow up.

5.8 Enamel Reduction Methods

Currently restorative dentistry is beginning to abide by the adage that 'less is more'. The preparation methods for PLVs have evolved from aggressive in nature to a more minimally invasive technique, or even no preparation. According to Fradeni et al the success rate of PLVs is dependent on the correct tooth preparation technique. A properly prepared tooth surface allows PLVs to be affixed to the acid etched enamel to achieve maximal strength (3, 30).

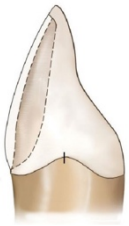
The primary goals of tooth preparation are as follows (6, 9, 23):

- Adequate thickness to fill porcelain and hard tissue;
- Adequate margins to cement the veneer;
- Preparation should be in enamel;
- Avoid sharp edges or angle which can cause stress inside the ceramics and the veneer;
- Prepare proper landmark to enable good seating of veneer.

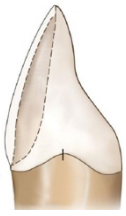
Mainly, a chamfer finish line is obtained close to the marginal gingiva and the enamel is reduced by 0.3-0.5mm. This provides better maintenance in enamel and a strong bonding. In the meantime, it also allows adequate thickness of the porcelain to be maintained. Most of the time, the preparation is placed supragingavally, which facilitates the proper brushing to avoid gingival trauma (25, 28).

In PLV tooth preparation there are 4 classical types have been discussed and modified with time (22, 25).

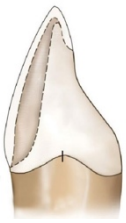
Table 2. Enamel Preparations Techniques of PLVs.[1]



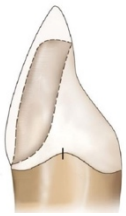
1. **Window preparation** - here the incisal edge is intact.



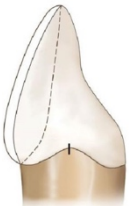
2. **Feather Preparation** - prepared to the height of the incisal edge without reducing edge.



3. **Bevel Preparation** - the Bucco-palatal bevel is prepared to the full width along with small reduction in the incisal length. The chamfer is extended into the palatal aspect. In case minimal preparation is required, the contact areas should still be maintained.



4. **Incisal overlap preparation** - this gives better aesthetics, sealing and stress distribution.



5. No Preparation Techniques

The preparation choice depends on the clinical situation of each patient and the existing conditions of the incisal edge. The type of extension made depends on the clinical case, and also on the stress distribution in between tooth and veneer (22, 25). Some defects in the anterior teeth, incisal angle fracture or caries of proximal area, require more preparation. Any pre-existing

[1] Authors granted written license to reproduce preparation images (25).

restorations must also be substituted. In these cases, it is better to select an alternative design to get maximum strength (6, 7).

There exists some controversy on whether to cover the incisal edge, or not, in the PLV preparation. (6) According to Hong, the tooth prepared with incisal coverage had high survival rate then without incisal coverage. The survival rate of butt-joint type might be higher than overlap and recommends for further studies (6).

Le Sage describes a different tooth preparation technique for PLVs (**Table 2**, **Figure 5**), where almost the enamel is not prepared. Furthermore, he describes a different classification to facilitate division between different preparation techniques. This is specifically suggested for minimally invasive techniques for PLVs. This classification is based on the available enamel amount of enamel and exposed dentin (12).

Table 3. Enamel Remaining Classification for PLVs.

Enamel Remaining classification for PLVs		
Reduction	**Facial enamel reduction**	**Enamel remaining percentage**
CL I No-Prep or practically prep less	Detectable with magnification with or without gingival line	95%-100%
CL II Modified prep-less or minimally invasive	Up to 0,5mm	80-95%
CL III Conservative design	0.5mm-1mm	50%-80%
CL IV Conventional	+1mm	Less than 50%

From the above classification, it is clear that the suggested ideal preparation for PLVs are **class I - II** which is almost not removing enamel during the preparation thus maintaining the maximum amount of hard tissue (12). Success of PLVs depends if the remnant enamel is more than 80% to get a maximum bond in between the prepared tooth surface and ceramic (4, 5, 23).

Pini suggests the following criteria of enamel reduction for preserving a healthy structural enamel (5, 6, 9, 10, 19, 23).

- Cervical third reduction 0,1mm
- Middle third reduction 0.2-0.5mm
- Incisal reduction 0.7-1mm

The Coach man has introduced three kind of guided preparation methods as a guide line for tooth preparation in PLVs (3).

1. **1st generation** preparation describes guided calibrated burs for facial and incisal edge reduction. These burs help to reduce the enamel in a uniform way. But this technique doesn't consider the position and anatomy of the tooth thus the risk of dentin exposure.
2. **2nd generation-Magnes** silicone indices technique-In this technique the silicone indices are made over the wax up guide to reduce the facial and incisal enamel. This technique allows for preparation of the tooth according to the tooth anatomy and also the future space of the restorative material.
3. **3rd generation-Gürel's** aesthetic pre-evaluative temporary (APT) technique-in this technique a temporary mockup is placed, and the mockup is used to determine the restorative materials to be added, which allows rapid, and more invasive technique. This technique guides the tooth position and anatomy of the final preparation thus allowing the clinician to analyse the aesthetics, function of PLVs before the final application of PLVs.

The recent development of CAD-CAM tooth preparation technique, such as FirstFit®, can be a guided tooth preparation and this technique allows the clinician to prepare not only teeth for PLVs but also can prepare previously treated tooth. This technique uses a 3D-printed guide and also a special hand piece to prepare the tooth. By using this technique the clinician is able to perform the preparation either in one step or two steps (3). Single-step PLVs are prepared before the preparation by using reduction guides and the veneers cemented on the same day. Two step-teeth are prepared by using the tooth guide reduction and free hand technique and cementing in the second visit. This study indicates that the most important factor for successful PLVs is that

preparation techniques and the preparation should be very minimal and always has to be in enamel structure.

5.9 Cementation of PLVs

Cementation of PLVs is the most sensitive step and should be done with extreme caution. The acid-etched surface of the prepared tooth creates micropores in the enamel. By treating with HF of ceramic PLVs, these pores facilitate adhesion and retention of porcelain in enamel (3, 27, 30). Light cured composite agents are widely used as a luting cement due to its bonding and colour reliability compared to dual-cured composites. Hence they help to produce bonding in between ceramic-composite, and enamel-composite (19).

The utilization of light-cured resins is useful due to their variations in colour selection and opacity. They provide a thin cementation, as compared to dual curing luting agent, with high fluidity and flowing rate that facilitates excess removal after the cementation (2). Resin cements are not used due to its thickness, which does not give any guarantee that the cement will be cured adequately (2).

Etching the ceramic with HF and application of silane coating is an often-used technique to get a clean surface of ceramic and retention (28, 30).

There are several reports regarding the number of veneers that should be fixed at a given time. Most clinicians recommend that two veneers be placed at a time starting from the central incisive. This method was observed to have a high survival rate. In contrast, other clinicians recommend fixing one veneer at a time. This fixation has to be done with own clinical experience, numbers of veneers and clinical difficulty of the case (1).

For PLVs or no prep veneers, the ideal selection of acid is HF, ideally 9.5% concentration, to produce micro pores. Due to this chemical procedure, adhesion in between restoration and tooth improves (2). Silane is a very thin layer of bonding agent which is applied to the internal surface of the PLVs, thus creating a chemical bond in between the composite and the ceramic to increase the mechanical bonding strength (28). The silane coating further enhances the adhesion of

ceramics to the enamel (28). It has been observed that applying silane agents before bonding plays a role in optimizing the bond between the light-cured composite and PLV (25, 28, 30).

Its low viscosity enhances the adhesion by increasing wettability, thus allowing resin to penetrate in to the micro pores of conditioned ceramic superficial surface. In addition to this, it increases the mechanical retention with PLVs and also prevents discolouration and micro leakage of composite resins to fixed PLVs (30). The reaction that occurs between ceramic and silane produces hydroxyl groups to create the chemical bond on the ceramic superficial surface; use of silane increases the bonding effect (28).

According to Pini (**Table 4**) different type of ceramics needed different etching times with HF to improve the micro bonding strength of PLVs to produce more durable PLVs (5).

Table 4. Type of Ceramics and "HF" applying criteria.

Type of Ceramic	Conditioning Method
Feldspathic	9,5% HF-2-2.5minutes; 1-minute washing; silane application
Leucite reinforced	9,5% HF-60seconds; 1-minute washing; silane application
Lithium disilicate	9,5% HF-20seconds; 1-minute washing; silane application

From this review, it has shown that feldspathic ceramics need more etching time in comparison to leucite reinforced and lithium disilicate (5).

It has been shown that use of silane coupling agent with 5% HF for 2-3 minutes is adequate to dissolve the glassy phase of ceramic and become porous. This increase in etching time, from the norm of 1 minute for the 9,5% concentration, improves the superficial micro pores and wettability in the ceramic microstructure of different kind of ceramics (30).

Due to the difficulty in cementation a recent development of the CAD-CAM guiding device is observing more popularity in usage. This is produced from the PLV's digital cast with gingival margin 2mm from the PLV and milled from a polymethyl methacrylate disk. The prepared PLVs seated in the device during the etching time which is loaded with the luting cement. After fixing, the excess is removed while the device is in place. This latest method provides better accurate etching and cementing (16). Due to the difficulty in two steps procedure the recently developed

one-time polymer is an interesting topic for PLVs cementation. This new self-etching glass primer is being used in CAD-CAM made PLVs along with lithium disilicate ceramics (7, 14, 16).

5.10 Survival rates

Success of any restoration depends on the effort of the dentist, as well as the patient's habits. Factors that influence the survival rate are (9, 11, 16, 23):

- Proper selection of case and planning;
- Minimal invasive preparation of teeth;
- Right selection of ceramics;
- Right laboratory procedures;
- Right selection of etching and cementing materials;
- Proper fixing of PLVs;
- Proper polishing;
- Post-operative follow up.

The following clinical factors also reflect on the survival rate (1):

- Proper adaptation of PLVs with the correct margins;
- Design of enamel reduction;
- Anatomical and functional condition of adjacent and abutment teeth.

Longitudinal studies have following four criteria as essential for success of PLVs (1, 31):

- Adequate strength, resistance of ceramics and proper etching and bonding;
- Bio compatibility of ceramics;
- Materials with characters of coefficient thermal expansion which is like tooth;
- Thermal conductivity of materials which are like enamel.

PLV restoration failures mainly occur in the first five years from application. This is due to following reasons (11):

1. Poor case selection;
2. Laboratory errors;
3. Technical errors.

According to Arif et al the common complication of PLVs are in the following-order (32):

- Chipping of PLVs;
- Secondary Caries;
- Debonding of PLVs;
- Recementation;
- Cracking line;
- Endodontic issues.

Santos et al believe that most complications of ceramic veneers arise due to fracture and this occurs usually during the initial years (11). The following survival rates have been reported in a retrospective clinical study 94,4 % - 5 years & 93.5 % - 10 years (1).

The design of the tooth preparation in relation to long term performance of PLVs has been demonstrated to be an important factor. According to a study conducted by Radz et al, the tooth prepared with an overlap design had 96.7% success rate and 100% for full veneer restorations (1).

Vitality of tooth plays a huge role in survival rate of PLVs. Beier et al observed that the survival rate of PLVs were 94.4% after 5 years, 93.5% after 10 years, and 82.93% at 20 years. A high failure risk was noticed in non-vital teeth (17). The patient's discipline directly impacts the success level of the PLVs. Patients with para functional habits (bruxism) have a high failure rate (7.7 times) and discoloration rate was relatively high in smokers (17).

In a study conducted by Layton et al, the authors found that feldspathic ceramic veneers have less failure rate and maximum survival rate. The 21 years survival rate for feldspathic PLVs are 96% (4). This study shows that PLVs fixed to maxillary anterior teeth had high survival rate in comparison to mandibular anterior teeth (4). PLVs which were cemented with light cured composite have a high survival rate with less marginal discolouration and caries, than that cemented with other composite cements (4). Burke suggests that high survival rate of PLVs is achieved when preparation was purely carried out in enamel without extending to dentin (3, 5, 19, 23). CAD-CAM made PLVs has high survival rate in comparison to other methods. The survival rate is 99% 96,4 after 5 years (15).

It is clear from these studies that PLVs can meet aesthetic and functional requirements of the patient. Therefore, PLVs can be considered as a treatment of choice to change tooth colour, size, and shape. It is suitable due to its considerably minor reduction of hard tissue as well as high survival rate.

5.11 Indications & Contraindications

5.11.1 Indications

In this subsection, we discuss the indications and contraindications that a dentist must consider. Selecting the right indication plays an important role to achieve high successful rate.

Indications were noted in the 1980s, but they were limited due to lack of proper adhesion systems and ceramics (1). Various classifications of indications have been proposed in the literature. Pascal then simplified and defined a formal classification system as follows (

Table 5) (30).

Table 5. Classification of indications of Pascal Magne.

Type I Teeth which are resistant to Bleaching.
IA Tetracycline discolouration.
IB No Response to external or internal bleaching.
Type II Major Morphological Modifications.
IIA Coronoid Teeth.

IIB Diastema and inter dental triangles to be closed.
IIC Augmentation of incisal length and prominence.
Type III Extensive Restoration.
IIIA Extensive coronal fracture.
IIIB Extensive Loss of Enamel by erosion and wear.
IIIC Generalized congenital and acquired malformations.

A study by Radz noticed that Type I and Type II can be used to solve the aesthetic component of PLVs, using minimally invasive or no-preparation techniques. On the other hand, Type III indications require extensive enamel removal. Hence, materials with greater thickness and resistance should be recommended for crown preparations (1).

We have performed an extensive survey of indications in literature and have mapped the indications to the formal classification by Pascal table (**Table 6**) presents this comprehensive list of indications. For each classification type, we present the following factors of the indications: development defects, colour, tooth position-space, occlusion, fracture and other factors, if any.

Table 6. Classification of Indication.

Indications of Porcelain Laminated Veneers						
Type	**Developmental Defects**	**Colour**	**Tooth Position/space**	**Occlusion**	**Fracture**	**Other**
Type IA		Tetracycline staining (1, 2, 3, 10, 19) Fluorosis (1, 5, 10, 11, 19, 23) Ageing (1)				
Type IB	Amelogenesis Imperfecta (5, 10, 17-19)					
	Peg Lateralis (1, 17, 19)					
Type IIA	Coronoid Tooth (10, 17)					
Type IIB			Diastema (mild to moderate) (1, 2, 5, 7, 10, 17, 23, 27) Multiple space closure. (5, 18, 23)	Inadequate contact points (23, 25)		

Type IIC				Increasing crown length & width (2, 6, 10)		
Type IIIA					Minor fracture of Anterior teeth and chipping (1, 6, 19)	
Type IIIB					Chemical, mechanical abrasion and wear (1, 17)	
Type IIIC						
Not in classification			Rehabilitation of Anterior guide (7)		Localized attrition (7)	Unaesthetic composites (17, 18)
	Hypocalcification (10, 19)		Lengthening of incisal edge (1, 4, 33)		Sensibility of tooth (1, 6, 10, 23)	Prosthetic correction (18)

When colour and position of the tooth is acceptable, PLVs seem to be an ideal solution for correcting discolouration caused by pulpal changes, developmental defects, mild distortions and tooth recontouring (1).

5.11.2 Contraindications

Despite the high aesthetic performance and success rate achieved by PLVs, there are a few limitations which require further tooth preparation, which can often be minimal or slightly more invasive. This directly affects the amount of dental enamel to be prepared and techniques to be selected cite (3, 19).

Patient habits play a great role, and in the following clinical conditions are contraindicated (1, 10, 25, 28):

- Para functional habits such as bruxism;
- Chewing pencils and other objects;
- Pressure creation due to ice crushing with anterior teeth;
- Poor oral health hygiene which provokes gingival and periodontal diseases;
- Mouth breathers;
- Smokers.

El Mowaby et al point out that the failure in providing a proper stable occlusion in the anterior teeth is considered to be a contraindications (10, 28):

- Occlusal classes III;
- Overbite;
- Severe crowding and malposition;
- Where inter occlusal distance is minimized;
- Deep vertical overlap in anterior portion, without horizontal overlap;
- Anterior cross bite.

Although PLVs are an alternative for tooth colour discoloration, it should not be the first option in cases where a simple tooth bleaching can solve the colour issues. This is mainly achieved by proper analysis of each case along with patient participation (1). Diagnosis and planning have a huge impact on PLV usage. El-Mowafy et al have reviewed that endodontically treated teeth or teeth with existing caries have to be treated with other alternatives, and not with PLVs (10). Furthermore, Layton et al point out that maxillary atresia, TMJ dysfunction, crowding and rotations should be treated before applying PLVs (4). According to Radz the etching element does not work effectively in deciduous-teeth, erupting teeth and in more discoloured teeth because bonding between the enamel and the PLV is prevented (1). Other contraindications evolve in situations where the enamel does not maintain at least 50% of the remnant enamel to withhold the bonding stress, and also exposes the dentin (4, 5, 10).

5.12 Advantages and Disadvantages of PLVs

5.12.1 Advantages of PLVs

The advantages of PLVs are many and speak to the various possibilities of indications. This is due to increasing demand for minimally invasive techniques, which are increasing to fulfil patients aesthetic need (6, 19). The characteristics of ceramics play a pivotal role in achieving successful PLVs. Due to their bio compatibility and high resistance properties, PLVs can provide the advantage of natural appearance similar to dental enamel (9, 12, 18, 21, 25).

Ceramics have the ability to retain less plaque than other materials, thus preventing gingival and periodontal tissue damages. In addition to these qualities, ceramics have also improved capacity

to withhold the chemical reaction in the oral cavity by maintaining a neutral electrolyte environment (9, 12).

One of the biggest advantages of using ceramics in PLVs is that they allow a conservative approach and are thus excellent options for minimally invasive or no preparation method (2, 5, 7, 11, 12, 14, 18, 19). According to Beier et al, ceramics have several other advantages in comparison to other veneering materials due to the following properties (5, 17, 23, 25, 28):

- No radio opacity or Translucency - this quality allows veneer to mimic the enamel;
- High resistance - Wear, abrasion and anti-stain properties are higher;
- Texture of PLVs can be easily achieved;
- Fluid absorption degree is lower than other materials - that is, it is resistant to fluid absorption;
- High colour and texture control - useful for better aesthetics;
- High bonding strength - bonded PLVs are very strong compare to other materials;
- High optical refractory qualities - gives a contact lens appearance;
- Porcelain surface is highly glazed and polished which resists accumulation of plaque.

Preparation of PLVs is minimal and confined only in the enamel without exposing the dentin or pulp and prevents post-operative sensibility. Also, the preparation is always performed supragingivally which itself prevents PLVs from remaining hidden under the gingiva (5, 12, 23).

Vaniglou et al describe that the preparation is almost minimal in terms of enamel reduction and this facilitates not requiring anaesthesia, and is an added advantage in patients who suffer from dental phobia (22).

The following are also considered to be important advantages(12, 23):

- In cases of minimum preparation and no preparation, there is no need of temporary provisional restorations;
- In certain circumstances, the procedure is reversible when necessary;

- Minimum stress is applied on veneers compared to other restorations.

5.12.2 Disadvantages of PLVs

Although PLVs are alternatives to other restorations and have achieved high survival rate, there are several negative outcomes which are described below.

The choice of the right ceramic plays a huge role in the success of PLVs, which directly correlates with the dentist's knowledge on ceramics and its proper application in PLVs production (5, 9). A study from McLaren et al confirmed that PLVs, despite being a minimally invasive preparation method, still need removal of a significant portion of dental enamel to achieve maximum bonding strength (5, 7, 12). In addition, PLV production involves several steps, which takes time and multiple visits to the dentist. PLV preparation also involves laboratory procedures and a lack of proper communication with the ceramist might produce inadequate PLVs (9).

The cementation step is very sensitive to moisture. The dentists therefore need adequate time to perform satisfactory isolation and protect the internal surface of these restorations and requires longer clinical time. Furthermore, due to fragility of PLVs in preparation and cementation steps, proper care has to be taken to avoid fracture from occurring (5, 27).

The losses and damages in enamel preparation resulted in the following (1, 5, 7):

- Lack of adaptation on material;
- Marginal colour changes;
- Roughness of PLVs.

PLVs can easily repaired with a composite resin but the repairs might produce staining in the fractured margin line of the composite and porcelain. The repair rate is very poor in comparison to composite veneers (27).

The following drawbacks of PLVs also need to be considered (5, 13, 16):

1. Cost - In comparison to composite ceramics, PLVs are expensive;
2. Colour - right shade selection is difficult. Also, colour changes after cementation is difficult

to modify;

3. High sensibility - PLV production is an indirect procedure which requires high precision impression and good quality lab work;
4. Too large and over shaped - This happens if the preparation is not maintained in the enamel.

5.13 CAD-CAM usages for PLVs

5.13.1 Overview

The main aim of developing computer technology in dentistry is to improve the quality of the dental restorations, appliances, and guide plates by reducing the production time. The digital systems allow highly predictable, perfect, and cost-effective material allowing a variety of ceramics to be used. This is an advantage over conventional fabrication of PLVs (20). CAD-CAM was first introduced in restorative dentistry in the mid-1980s. Initially, immediate chair side in-lays ,onlays and PLVs were applied. CAD-CAM was only capable of taking 2D images, but due to lack of storage technology, it had a high fabrication time (13, 20). After the revolution from 2D to 3D technology, CAD-CAM became very useful for the production of chair side restorations. It is now one of the most-adopted systems by dentists (13, 15, 20).

The traditional impression technique was replaced by a digital impression technique using an intraoral digital scanner. The digital scanner consists of an intraoral camera which captures the tooth and soft tissue structural data. This is transformed by computer software to a 3D format in real time. This allows quickly displaying the results on a monitor that can be used by the dentist to explain the procedure to the patient (13, 20). With this design the dentist can perform pre-laboratory adjustments such as marking margins, adjusting occlusal contacts, refining proximal contact areas with adjacent teeth and planning the colour with the patient before sending to the milling procedure (15, 20). From the obtained optical impression, the restorations are milled from prefabricated porcelain.

The workflow of the CAD-CAM technology is as follows (13, 20):

1. Tooth preparation;

2. Intra-oral scan;
3. Adjustment of design;
4. Milling of the restoration;
5. Check-up and cementation.

Siqueira et al showed that PLVs fabricated with this system can precisely simulate the veneer, which results in better outcomes than with the conventional method (3, 14).

5.13.2 Advantages and Disadvantages

Compared to traditional techniques, the restorations made with CAD-CAM have many advantages including, speed, quality, appearance and ease-of-use (3, 13, 15, 20). The CAD-CAM system is highly recommended in cases that require greater conservation and accuracy and allows production of PLVs with proper specification and detail according to each individual case (5, 13, 14). The veneers produced by CAD-CAM technology have a natural appearance like dental enamel. In addition, traditional impressions are not required thus reducing the time and visit number where patients can avoid the gag inducing traditional impressions. (3, 13, 20). The impressions taken by this technology are faster and easier and can also produce the restoration on the same day if dentists have a chair side milling machine, which removes requirement for a second visit and wearing of temporary provisional veneers (13, 15, 20).

Both arches can be scanned and digital impression can be taken at the same time. Furthermore one time conditioning and silanization technique along with this technology further reduces the production time of the PLVs (3, 14, 16, 20). The impressions which are taken with this technology can be analysed immediately with the software and corrected before tooth preparation; this analysis permits checking the space required for restoration during the design phase. Facial photos can then be integrated with intra-oral scan and analysing the outcome of future PLVs (15, 20).

The utilization of the CAD-CAM technique can provide the dentist with an array of different kinds of ceramics to choose from which can be tailored to each patient. Furthermore that CAD-CAM can be an ideal solution for patients who need immediate veneers (3, 13, 15).

The introduction of Bluecams camera, which produces accurate impressions, eliminates blurred imaging and yields a high-quality image which the dentist can use to decide the future veneer design and better marginal fit (15). Nejatdidanesh demonstrated that the use of this technique is increasing because it reduces the workload by producing an easier digital planning and allows controlling the characteristics of the piece to be reproduced. By collecting characteristics such as colour, shape and contour, CAM simplifies the production of the PLV (15).

One of the biggest advantage of CAD-CAM is that the areas which are difficult to scan can be simply captured without any need to repeat the entire scanning procedure (20). In addition, photos or 3D scan of the face can be integrated with the existing database allowing a real time feedback of facial appearance allowing rapid changes in the treatment plan which were not possible with the analog stone models (3). The recent advances in the CAD-CAM technology facilitates the tooth preparation and cementation by producing a guide plate, which itself allows dentists to minimise the preparational and cementation errors (3, 16). This technology allows not only to produce PLVs but also is useful in fabrication of ceramic fragments in fractured anterior teeth. However, the dentist should be accurate to locate the fracture line to minimize restoration errors.

The other advantages of this technology can be elaborated in the following manner (3, 12, 15, 20, 25):

- Variation of selecting ceramics-in the milling process feldspathic, leucite, lithium disilicate blocks can be used;
- The dentist can select the shape and colour using a database;
- Computing storage is another advantage over traditional physical storage of models which can chip or break if stored improperly;
- Allows to produce high quality PLVs due to lack of internal defects of prefabricated ceramic blocks;
- Reduces the human error of taking manual impression and laboratory procedures;
- The quality of the PLVs are far better than traditional methods;

- The software's allow to detect the proper occlusal contacts, undercuts, sharp margins, corners, and rough surfaces to avoid the proportional errors.

The advantages of CAD-CAM also extend the durability of materials used in the manufacturing process. CAD-CAM veneers show a 95% survival rate in 2 years without any bio and technical complications and 93% in 5 years (15).

Even though this technology possess many advantages such as increased speed and efficient in terms of quality of the final PLVs, there are few disadvantages discussed in literature. The high cost of equipment, complexity of usage and lack of computer knowledge among dentists seems to be a big disadvantage. In addition, preparation depends on the dentist's skills as tooth preparation and cementing is still carried out entirely manually according to the traditional technique (13, 20). Even though the impression is optical, all other factors such as moisture control, haemostasis, soft tissues contour and retraction have to be taken with care to obtain an accurate impression and cementation (12, 14, 16).

The other outcomes of this technology are:

- When tooth wear is excess it is inadequate to receive the PLV part to be bonded;
- Sharp angles are more prone to future fractures; thus, the system cannot compensate or correct the angle prepared by the dentist.

6 Conclusion

PLVs are becoming extremely popular in restorative dentistry due to its high aesthetic and functional performance. We discussed how this advancement was made possible due to the development of new ceramics, etching and bonding systems; and the increasing usage of technologies like CAD-CAM. Furthermore, this technology enhanced guided tooth preparation and cementation which itself is an added advantage in applying of PLVs.

The clinical outcome with PLVs depends on the proper selection of clinical cases, correctly measuring the advantages and disadvantages of PLVs compared to other materials and using case specific techniques to be applied to achieve the high aesthetic results. Along with the real indications, the technique of tooth preparation and right selection of the ceramic and PLVs cannot be modified or repaired once it has been fixed and it may be expensive compared to other clinical techniques.

The latest development of technology, like CAD-CAM, and materials allows dentists and ceramists to produce faster, more durable, and long-lasting veneers to satisfy the patients requirements.

There are many developments that is expected to bring further benefits in the future. It is expected that even less invasive methods will be developed. Improvement in materials and technology will also result in even better aesthetic and functional results.

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