TOPIC REVIEW

Current status of materials for posterior indirect adhesive restorations

Estado actual de los materiales para la fabricación de restauraciones indirectas adhesivas posteriores

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ABSTRACT

The current materials for manufacturing posterior indirect adhesive restorations (PIAR) can be divided into ceramics, resin composite materials, and hybrid materials. Each one presents different composition, mechanical and optical properties, manufacturing techniques, and survival rates. The aim of this article was to review relevant materials and techniques currently available for manufacturing PIAR. A review of literature for randomized clinical trials, systematic reviews and literature reviews related to PIAR was performed using MEDLINE, PubMed, and Scielo. It is concluded that these materials show high durability and a good clinical performance. Furthermore, the survival rates of these restorations are over 90% for dental ceramics and over 85% for resin composites in the first couple of years with a minimum decrease over time. Thus, PIAR are a conservative and predictable option for restorations of posterior teeth and the choice of material used should always be weighed together with different factors including antagonist material, parafunctional habits, esthetics, and treatment cost.

Keywords: *dental materials, ceramics, composite resins, permanent dental restoration*

Resumen

Los materiales actuales para la fabricación de restauraciones adhesivas indirectas posteriores (PIAR) pueden dividirse en cerámicas, resinas compuestas y los materiales híbridos. Cada uno presenta una composición, propiedades mecánicas y ópticas, técnicas de fabricación y tasas de supervivencia diferentes. El objetivo de este artículo fue revisar los materiales y técnicas relevantes actualmente disponibles para la fabricación de PIAR. Se realizó una revisión de la literatura para ensayos clinicos, revisiones sistemáticas y revisiones bibliográficas relacionadas con PIAR utilizando MEDLINE, PubMed y Scielo. Se concluye que estos materiales muestran una alta durabilidad y un buen rendimiento clínico. Además, las tasas de supervivencia de estas restauraciones son superiores al 90% en el caso de las cerámicas y superiores al 85% en el caso de resina compuesta en los dos primeros años, con una disminución mínima con el paso del tiempo. Así pues, las PIAR son una opción conservadora y predecible para las restauraciones de dientes posteriores y la elección del material utilizado debe ser evaluada siempre considerando diferentes factores, entre los que se incluyen el material antagonista, los hábitos parafuncionales, la estética y el costo del tratamiento.

Palabras clave: *materiales dentales, cerámica, resinas compuestas, restauración dental permanente*

Submitted: august 15/2023 - Accepted: april 28/2025

How to quote this article: Mas-Lopez J, Melendez D, Tay LY. Current status of materials for posterior indirect adhesive restorations. Rev Fac Odontol Univ Antioq. 2025; 37(2): e354646. DOI: http://dx.doi.org/10.17533/udea.rfo.v37n2e354646

INTRODUCTION

Posterior indirect adhesive restorations (PIAR) are a conservative therapeutic alternative to restore decayed, fragilized teeth with medium and extensive tissue loss, prior to the decision to place a conventional crown.[1] The increase in the clinical use of this type of restorations has allowed the development of materials such as composites for direct and indirect use and dental ceramics that present adequate esthetic and biomechanical properties.[2] Moreover, there has

been a remarkable improvement in the manufacturing techniques and adhesive protocols that allow a greater longevity of these restorations.[3]

Currently, there are three groups of materials for the fabrication of esthetic inlays, onlays, and overlays, such as dental ceramics, resin composites, and hybrid materials, and within these groups there is a complex variety of materials that have been improving their physical and mechanical properties as well as their clinical indications (Table 1).[4] Despite the growing body of literature on PIAR, there remain significant gaps in the comparative analysis of materials and techniques, particularly regarding long-term clinical outcomes, material selection and cost-effectiveness.

Table 1. Characteristics of the materials used for PIAR

Materials			Manufacturing technique	Flexural strength	Composition	Longevity	Commercial brands
Dental ceramics	*Glass ceramics*	Feldespathic ceramics	Sintering and CAD-CAM	70 - 90 MPa9	Glass phase: feldspar based on silica and alumina. Crystalline phase: various types of particles that form the crystalline phase in a percentage of less than 17%.	94,7% after 5 years 90,6% after 8 years 85,7-89% after 10 years19 92% to 95% at 5 years and 91% at 10 years4	Allceram (Degudent), Vita VM 13, Vita Mark II, Vitablocs TriLuxe, Triluxe Forte, RealLife blocks (Vita Zahnfabrik), Cerec Blocs (Sirona Dental Systems)
		Leucite-reinforced feldespathic ceramics	Sintering and CAD-CAM	120 -160 MPa9	Glassy phase: feldspar based on silica and alumina. Crystalline phase: leucite crystals in a percentage of less than 45-55%.		IPS Empress Aesthetic (Ivoclar Vivadent), Optec OPC (Jeneric Pentron), Authentic (Jensen), y Finesse All-Ceramic (Dentsply), Empress CAD (Ivoclar-Vivadent), Paradigm C (3M/Solventum)
		Lithium disilicate ceramics	Heat-/hot-pressing technique and CAD-CAM	360 - 470 MPa21	70% of $Li_2Si_2O_5$ crystals entangled in the form of fine rods, and a smaller amount of lithium orthophosphate (Li_3PO_4) crystals.	96,3% after 6,6 years 94% after 8,5 years25	IPS e.max Press e IPS e.max CAD (Ivoclar Vivadent), 3G (Jeneric Pentron), Rosseta (Hass)
		Zirconia-reinforced lithium silicate ceramics	Heat-/hot-pressing technique and CAD-CAM	370 and 460 MPa26	Lithium-metasilicate (Li_2SiO_3) glass–ceramic matrix that is reinforced with approximately 8–12% of zirconium dioxide grains (ZrO_2), presenting a fine-grained microstructure (Li_2OZrO_2-SiO_2)29	99% after one year30	Vita Suprinity PC (Vita Zahnfabrik, Bad Säckingen, Germany); Celtra Duo (Dentsply Sirona, Hanau-Wolfgang, Germany), Vita Ambria (Vita Zahnfabrik, Bad Säckingen, Germany), Celtra Press (Dentsply Sirona, Hanau-Wolfgang, Germany)
	Polycrystalline ceramics	4Y-TZP	CAD-CAM	850 - 900 MPa31	4 mol% yttria-stabilized tetragonal zirconia (4Y-TZP) and 25% cubic phase	-	Zpex 4 Tosoh, IPS e.max ZirCAD MT (Ivoclar Vivadent), Zenostar MT (Wieland Dental), Katana ST/STML (Kuraray Noritake)
		5Y-TZP	CAD-CAM	600 MPa26	Zirconia in cubic (50%) and tetragonal (50%) phases	-	Lava Esthetic (3M/Solventum), Cercon xt (Dentsply Sirona), BruxZir Anterior (Glidewell), Prettau Zirconia (Zirconzhan), Katana UT/UTML (Kuraray Noritake)

http://dx.doi.org/10.17533/udea.rfo.v37n2e354646

Resin composites	*Conventional resin composites semi-direct technique*	Handmade		Matrix, usually dimethacrylate, fillers, a silane coupling agent to bind the filler to the matrix, and chemicals that modulate the polymerization reaction	100% after 3.5 years41	Filtek Z350 (3M/Solventum), Empress direct (Ivoclar Vivadent), Vittra APS (FGM), Opallis (FGM), Estelite Omega (Tokuyama), Palfique LX5 (Tokuyama), Forma (Ultradent).
	Indirect resin composites	Handmade, complementary techniques and CAD-CAM	200 Mpa48	Syringes: matrix, fillers, a coupling agent CAD-CAM blocks: matrix, spherical particles of colloidal silica and ZrO2 dispersed in agglomerated and unagglomerated form (80% by weight, 65% by volume) embedded in a dimethacrylate resin (Lava Ultimate)	85,7% after 2 years50	Artglass Launched (Heraeusl- Kulzer), Targis Launched (Ivoclar Vivadent), SR Adoro (Ivoclar Vivadent), Paradigm MZ100 (3M/Solventum), TESCERA ATL (BISCO INC), Sculpture plus (Pentron), Vita ZetaLC (Vita Zahnfabrik), Pearleste E2 (Tokuyama). CAD-CAM blocks: Lava Ultimate (3M/Solventum), Cerasmart (GC-Corp), Shofu Block HC (Shofu-Inc.), Brilliant Crios (Coltene)
Hybrid materials	*Polymer-infiltrated ceramic network- PICN*	CAD-CAM	160 Mpa52	Polymer-infiltrated ceramic network. Cross-linked polymers of urethane dimethacrylate and triethylene glycol dimethacrylate (14% by weight, 25% by volume) and a network of fine open pore feldspar ceramic structure (86% by weight, 75% by volume).	97,4% after 3 years17	VITA Enamic (VITA Zahnfabrik)

Fuente: por los autores

The need to synthesize current knowledge while critically analyzing the advancements and limitations of available materials and techniques is of outmost importance for contemporary dentistry. In doing so, it supports clinicians in making evidence-based decisions, contributes to laboratory workflow optimization, and serves as a valuable academic resource. Therefore, the purpose of this review is to present the materials and techniques currently available for the fabrication of PIAR.

METHODS

Article selection criteria

A comprehensive literature review was conducted to identify relevant studies addressing materials and techniques used for posterior indirect adhesive restorations (PIAR). The following inclusion and exclusion criteria were applied:

Inclusion criteria

- Articles published in English, Spanish, or Portuguese.
- Clinical studies, in vitro studies, systematic reviews, meta-analyses, and narrative reviews that discuss materials, techniques, or adhesive protocols for PIAR (including inlays, onlays, and overlays).
- Articles addressing the performance, longevity, physical and mechanical properties, or clinical outcomes of resin composites or dental ceramics used for PIAR.

Exclusion criteria

- Studies not related to posterior restorations or adhesive procedures.
- Articles focusing exclusively on anterior restorations.
- Editorials, conference abstracts, and letters to the editor.
- Studies lacking detailed information on materials, techniques, or adhesive protocols.

Search strategy and databases

An electronic search was performed across three major databases: MEDLINE, PubMed, and SciELO. The searches were conducted using combinations of the following keywords and MeSH terms: "posterior indirect adhesive restorations," "inlays," "onlays," "overlays," "dental ceramics," "resin composites," "adhesive techniques," and "restorative materials." Boolean operators (AND, OR) were used to optimize the search results and refine article relevance.

In PubMed, filters were applied to limit the results to studies published within the selected date range and to include only studies involving humans. The MEDLINE and SciELO searches were similarly refined using keyword mapping and language restrictions. Duplicates were removed, and all titles and abstracts were screened by two independent reviewers. In total, the titles and abstracts of 70 articles were reviewed, of which 59 were selected for full-text reading and inclusion in the development of this review.

DENTAL CERAMICS

Glass ceramics

Glass ceramics are materials composed of metal oxides bonded together by means of a high temperature heat treatment where the glassy and crystalline phases are differentiated in the final structure.[5] The fundamental difference between dental ceramics and those used for other purposes lies in the kaolin content, which represents more than 50% of the mass in non-dental porcelains.[6] In the case of glass ceramics, they contain little or no kaolin but do contain pigments and compounds that provide fluorescence. Thus, the glassy phase in dental ceramics is usually linked to esthetics, meanwhile the crystalline phase is related to mechanical properties. The term "glass ceramics" is given by the presence of an important percentage of this glassy phase, which has been modified to improve its physical properties.[7]

Feldspathic ceramics

This ceramic is mainly formed by a glassy phase containing feldspar based on silica and alumina joined to various types of particles that form the crystalline phase in a percentage of less than 17%.[8] Due to this characteristic, their flexural strength is the weakest among ceramics (70 and 90 MPa)[9] which means that they can only be used in restorations that do not receive high occlusal forces.[10] However, the crystalline phase has a refractive index similar to that of the glassy matrix, which contributes to the translucency of the entire structure, making it a highly esthetic option.[11]

Feldspathic ceramics are mainly use for the fabrication of veneers, porcelain-fused-to-metal (PFM) crowns and bridges, veneering material for lithium disilicate and zirconia frameworks, and PIAR.[8] The composition of this ceramic consists of a variety of oxides such as SiO_2, Al_2O_3, K_2O, Na_2O.[12] The fusion of these compounds produces feldspar glass and leucite crystals. This structure has high translucency, but the crystals do not have a significant strengthening effect.[10] The matrix of feldspathic ceramics is mainly SiO_2, where a central silicon cation (Si^{4+}) is covalently bonded to four oxygen anions located at the corners of a regular tetrahedron. In the case of feldspar porcelains, alkali ions, such as sodium or potassium, occupy sites that allow them to bind to the electrons of the unbalanced oxygen ions.[5]

Leucite-reinforced feldspathic ceramics

By modifying the heat treatment used in their fabrication, leucite crystals can be obtained in adequate quantity and size to achieve greater mechanical reinforcement of the final structure.[13] Thus, the percentage of the crystalline phase ranges between 45-55% and the flexural strength between 120 and 160 MPa, allowing restorations to be subjected to higher occlusal forces.[9]

These ceramics are used for veneers, crowns (anterior teeth and premolars) and PIAR.[14] The feldspathic and leucite-reinforced feldspathic dental ceramics used for PIAR were initially made using the refractory die technique, which consists of mixing the ceramic powder with a liquid such as water or a mixture of water and glycerin to form a malleable mass that is then applied on a refractory die using different opacities and pigments with a handmade technique, which will allow characterizing and personalizing a restoration achieving high esthetics.[15] The modeling of the ceramic under this technique results in small bubbles inside the structure, decreasing its resistance. Also, successive duplication eventually generates a greater mismatch.[8]

On the other hand, feldspathic ceramics were the first to be used with the CAD/CAM system in 1985 mainly for the elaboration of inlays and onlays.[16] This manufacturing technique uses an intraoral scanner to make a digital impression; then, through a computer software, the design and the milling of the block is performed.[17] A restoration with better adaptation, mechanical properties, and shorter fabrication time but with limitations in aesthetics due to the use of monochromatic blocks that require additional staining.[18] Nonetheless, this drawback has been overcome by the incorporation of polychromatic blocks.

Clinical trials evaluating the longevity of inlays showed survival rates of 90.6% after 8 years and 85.7-89% after 10 years.[19] Similarly, Morimoto et al. assessed the survival rate of ceramic inlays, onlays and overlays finding 92% to 95% at 5 years and 91% at 10 years. However, failures were related to fractures or chipping (4%), followed by endodontic complications (3%), secondary caries (1%) and adhesive failures (1%).[4]

Lithium disilicate ceramics

Lithium disilicate is a ceramic consisting of 70% $Li_2Si_2O_5$ crystals entangled in the form of fine rods, and lithium orthophosphate crystals in a small quantity uniformly dispersed in the glass matrix.[20] The presence of these crystals in the ceramic prevents the propagation of fractures in the material, increases the mechanical strength, resulting in a flexural strength of 360-400 MPa.[21] Ingots for the press technique are available in six levels of translucency: high translucency (HT), medium translucency (MT), low translucency (LT), medium opacity (MO), high opacity (HO) and a new proposal called Impulse (I) with a higher opalescence ideal for veneers on bleached teeth while CAD/CAM blocks feature five levels: high translucency (HT), medium translucency (MT), low translucency (LT), medium opacity (MO) and Impulse (I). The ingots are available in monochromatic and polychromatic versions (IPS e.max Press Multi), which allows for a more natural shade transition, while the CAD/CAM blocks are available in monochromatic versions only. On the other hand, due to the addition of metal oxides such as V^{3+} (yellow), Ce^{4+} (yellow) and Mn^{3+} (brown), various shades are available (from 5 to 16 shades of the Vita scale and 4 bleach shades).[21] Other details can be characterized with ceramic stains or covered with feldspathic ceramic using the cut-back technique.

This material is used for the fabrication of inlays, onlays, veneers, crowns (anterior teeth and premolars), implant-supported crowns and 3-unit bridges up to the second premolar.[22] For PIAR, high (HT) and medium translucency (MT) blocks are generally used.

The typical composition of lithium disilicate is based on 57-80 wt.% SiO_2, 11-19 wt.% Li_2O, 0-13 wt.% K_2O, 0-11 wt.% of P_2O_5, 0-8 wt.% of ZrO_2, 0-8 wt.% of ZnO, 0-5 wt.% of Al_2O_3, 0-5 wt.% of MgO and 0-8 wt.% of coloring oxides.[21, 23] On the other hand, this composition was modified by incorporating ≈10% by weight of zirconia to reinforce the ceramic structure by preventing crack propagation and presenting improved mechanical properties and the highest aesthetic demands.[24]

For PIAR fabrication, two methods are used: CAD/CAM and the press technique. Lithium disilicate CAD/CAM blocks are manufactured on a three-stage crystallization process used to precipitate lithium disilicate. These blocks are in a "blue state" and exhibit poor mechanical properties that facilitate their milling into the desired restoration. After milling the restoration to the desired shape, the material is heated at 850°C for 20-31 min in a furnace, where the lithium metasilicate crystals fully react with the surrounding glassy silica through a solid-state reaction to form small, rod-shaped, interlocking lithium disilicate crystals, which gives glass-ceramics their high flexural strength 360 MPa.[21]

For the fabrication of restorations using the press technique, a wax pattern is coated on a casting cylinder and taken to the furnace for removal and subsequent injection of the material.[21]

Lithium disilicate PIARs demonstrate a high success and survival rate. In a study by Fotiadou et al., 250 lithium disilicate restorations were evaluated after a period of 6.6 years placed by university students with different levels of training. The survival and success rates of the indirect lithium disilicate restorations were calculated at 6.6 years as 96.3 % and 93.8 %, respectively. At 8.5 years, the survival rate was calculated at 94 % and the success rate at 83.8 %.[25]

Zirconia-Reinforced Lithium Silicate

Zirconia-reinforced lithium silicate (ZLS) ceramics represent a new class of glass-ceramics developed to enhance both the mechanical and optical properties of traditional lithium disilicate materials. These ceramics typically contain 10% by weight of zirconia (ZrO_2) homogeneously dispersed within a fine-grained lithium silicate crystal matrix. The addition of zirconia significantly improves the mechanical performance by increasing resistance to crack propagation and enhancing flexural strength, which can range between 370 and 460 MPa depending on the processing technique.26 ZLS ceramics feature an extremely fine microstructure, composed of a lithium metasilicate (Li_2SiO_3) glass–ceramic matrix reinforced with about 8–12% zirconium dioxide (ZrO_2) particles, resulting in a fine-grained microstructure (Li_2O-ZrO_2-SiO_2) following the crystallization process.[27]

ZLS ceramics offer superior translucency and natural opalescence, making them ideal for esthetic restorations in anterior and posterior regions. Products such as Celtra Duo and Vita Suprinity are available in various shades, including classical Vita shades and bleach tones, and in translucency levels such as High Translucency (HT) and Translucent (T). ZLS ceramics are processed primarily via CAD/CAM systems Vita Suprinity PC (Vita Zahnfabrik, Bad Säckingen, Germany); Celtra Duo (Dentsply Sirona, Hanau-Wolfgang, Germany) as well for pressing technique—Vita Ambria (Vita Zahnfabrik, Bad Säckingen, Germany); Celtra Press (Dentsply Sirona, Hanau-Wolfgang, Germany).[28] Celtra Duo is unique in that it can be used in both a milled-only condition or after an additional firing process to increase its mechanical strength (up to 500 MPa). This dual-use option makes it highly versatile for same-day dentistry. Due to their enhanced mechanical performance and high esthetic potential, ZLS ceramics are suitable for a wide range of complex clinical applications, including PIAR, veneers, as well as anterior and posterior crowns, and single-tooth restorations on implant abutments.[29]

Bahn et al. assessed the clinical outcomes of ZLS indirect restorations and reported a 99% survival rate after one year. These results suggest that ZLS materials demonstrate promising short-term clinical effectiveness for PIAR; however, extended follow-up studies are necessary to evaluate their long-term durability.[30]

Polycrystalline ceramics

Zirconia

Zirconia or zirconium oxide is a polycrystalline ceramic since it contains little glassy phase and is mainly a dense crystal network that reduces crack propagation, which provides excellent mechanical properties.[31] Thus, its flexural strength ranges from 800 to 1500 MPa, higher than glass ceramics. However, this type of ceramic is less translucent and opaquer.[32] Zirconia blocks are available in monochromatic, manufactured in a single color, and multilayered presentations with different shades. Due to the improved mechanical and esthetic characteristics available for this material, nowadays restorations can be obtained with a smaller space requirement.[33]

Depending on the type of zirconia used, it is indicated for the fabrication of multi-unit bridges, adhesive bridges, anterior and posterior crowns, implant crowns, veneers, inlays and onlays.[31]

Zirconia exists as a natural mineral called baddeleyite which contains 80% to 90% zirconium oxide (ZrO2). Zirconium oxide exists in three phases: monoclinic (from room temperature to 1170 °C), tetragonal (from 1170 C to 2370 °C) and cubic (from 2370 °C to the melting point).[34] The zirconia

production process begins when pure zirconia in its first phase, the cubic phase, crystallizes at high temperatures and forms the tetragonal phase, then changes to the monoclinic phase as it cools, which generates a 4% volume increase.[31] This can be prevented by adding stabilizing oxides, for example: CaO, MgO, Y2O3, and CeO2, which keep the crystalline structure in the tetragonal phase. Currently, this material can be found on the market as zirconia partially or totally stabilized with yttrium oxide (Y-TZP), zirconia stabilized with cerium (Ce-TZP/AL2O3), zirconia partially stabilized with magnesium, etc.[34] Zirconia is processed mechanically, from pre-sintered or fully sintered blocks or discs made from zirconia powder, which are processed using CAD/CAM systems.[31]

The classification of zirconia in dentistry has evolved to encompass various types based on yttria content, microstructure, and intended clinical applications.

Yttria-Stabilized Zirconia (YSZ) Types:

- 3Y-TZP (3 mol% Yttria-Stabilized Tetragonal Zirconia Polycrystal): Conventional partially stabilized zirconia, developed in the early 2000s, has a flexural strength of 1000 to 1200 MPa and a high opacity due to multiple interfaces and numerous crystal structures that dissipate the passage of light giving it a characteristic opaque white color. Known for its high strength and fracture resistance, it's commonly used for posterior crowns, bridges, and implant abutments. However, its lower translucency limits its use in esthetic zones. To overcome this disadvantage, the restorations can be veneered with a glass ceramic after being individually fabricated and used as infrastructure for crowns and bridges.[35]
- After some years, a new 3Y-TZP was introduced in the market in 2012-2013 and presented as main characteristic the reduction in number and size of the aluminum oxide grains (0.05% AL2O3), which present a refractive index very different from that of zirconia. Due to the relocation of the AL2O grains within the internal structure, high light transmission was achieved, as well as high flexural strength of 1000 to 1200 MPa and long-term stability. It is also tooth-colored opaque and is used as a framework for ceramic veneered crowns and bridges.[31]
- 4Y-TZP (4 mol% Yttria): Since 5Y-TZP does not meet the mechanical demands of multi-unit fixed dental prostheses, 4 mol% yttria-stabilized tetragonal zirconia (4Y-TZP) was developed to represent a midpoint between 3Y-TZP with reduced Al2O3 and 5Y-TZP offering a balance between strength and translucency. It has a flexural strength of 850 - 900 MPa and 25% cubic phase, which gives it a high translucency for use in veneers, crowns, PIAR and monolithic bridges.[36]
- 5Y-TZP (5 mol% Yttria): In 2015, this type of zirconia was introduced at The International Dental Show in Cologne-Germany, because the translucency of 3Y-TZP was still lower to that of glass ceramics. This is a fully stabilized zirconia with a mixed structure of cubic (50%) and tetragonal (50%) phases, which means that there is no transformation of the structural phases during the manufacturing process. The cubic crystals, obtained due to the addition of a high concentration of yttrium oxide, present a greater volume compared to the tetragonal ones as well as greater isotropy, which makes the material more translucent since the light dissipates less around the crystals and residual porosities, and they can reflect the incident light in a more uniform way. This zirconia has a flexural strength of 600 MPa and a high translucency which allows its use in monolithic form characterized with stains for veneers, crowns, and inlays.[31] However, the increased yttria content reduces its strength, limiting its use in high-stress areas.

Gupta et al. evaluated the survival rate and marginal integrity of single partial- and full-coverage monolithic zirconia restorations and found that monolithic zirconia is a viable option. Occlusal contact at the restoration margins should be avoided.[37] Similarly, Waffaie et al. evaluated the fracture resistance of maxillary premolars with Class II inlay and onlay preparations and found that premolar teeth restored with zirconia ceramic inlays and onlays showed properties comparable to that of intact teeth.[38]

RESIN COMPOSITES

Conventional resin composites

In recent decades, the use of resin composites has increased for both direct and indirect restorations, in parallel with the improvement of their esthetic and mechanical properties and their low cost, making them the first choice for PIAR.[39] They can mimic the tooth structure, have a modulus of elasticity similar to the tooth structure and adhesion that allows a biomechanical behavior as a whole.[40]

The semi-direct technique was developed in the 1980s with the aim of replacing amalgam inlays with composite resin inlays[41] and consists of using a flexible die to fabricate PIAR in the dental office, which allows the treatment to be carried out in a single appointment, without extra laboratory costs or provisional restorations, thus serving as a quicker, more affordable alternative compared to indirect resin composites or ceramic restorations. In this technique, an impression of the prepared tooth and adjacent teeth is taken with alginate or condensation silicone and die silicone is injected into the mold to obtain the die. After the silicone hardens, and the clinician creates the resin composite restoration.[42]

Direct resin composites are used for the fabrication of inlays through this technique. They consist of a combination of polymer matrix, fillers, a silane coupling agent to bond the filler to the matrix, and a photoinitiator system.[43] Due to different modifications in the size of their filler, they can be classified into macrofilled, microfilled, hybrid, microhybrid and nanofilled resin composites, the latter providing excellent polishability, abrasion resistance, less polymerization shrinkage and greater color stability, while increasing flexural and tensile strength, as well as achieving good esthetics by using various opacities and characterizing the restoration with pigments.[44] The main advantage of this technique is the possibility of making a PIAR in a single appointment and at low cost, as well as the reduction of shrinkage stress, anatomically correct proximal contacts, and the improvement of the degree of conversion due to the possibility of light-curing on all sides of the restoration and exposure to heat and pressure.[42, 45]

Spreafico et al. evaluated the clinical performance of direct and semi-direct Class II hybrid resin restorations for 3.5 years and found that there is no significant difference for restorations using both techniques.[46] Similarly, Angeletaki et al. evaluated the long-term clinical performance of direct resin composite restorations versus resin composite inlays in posterior teeth finding that the two techniques did not present significant statistical differences to recommend one technique over the other.[47]

Indirect resin composites

Indirect resin composites are materials based on a polymeric matrix and inorganic filler, whose main purpose is to avoid complications when directly restoring wide cavities in posterior teeth, thus reducing polymerization shrinkage stress, marginal filtration, postoperative sensitivity and secondary caries, as well as improving the physical properties of the material by means of additional polymerization techniques.[48] The polymerization of these composites is never complete, reaching a degree of conversion of 70 to 80%, since in addition to photoactivation, polymerization is carried out with an increased temperature and pressure. In order to improve even more the degree of polymerization, nowadays there are blocks of composites, which present a much more compact structure providing better mechanical properties (such as hardness, flexural strength, elastic modulus, compressive strength, tensile strength, fracture resistance, and wear) extending its use in different clinical situations, this polymerization is achieved in an industrial way obtaining a degree of conversion of 90 to 95%.[49]

Indirect resin composites have a composition based on Bis-GMA monomers and filler that varies in content, particle type and size. By increasing the filler loading, mechanical properties and wear resistance are improved, and by reducing the organic resin matrix, polymerization shrinkage is reduced.[50] Also, different types of fibers have been added to further improve the properties of indirect resin composites such as: polyethylene fibers, carbon/graphite fibers and glass fibers, which act to stop fracture propagation while the resin matrix acts to protect the fiber and fix its geometric orientation.[51]

On the other hand, an example of resin composite blocks is Lava Ultimate (3M ESPE) which launched as a CAD/CAM block in 2011 and is an example of a resin composite with dispersed fillers. This is based on the polymerizable resin composite Filtek Supreme Ultra (3M ESPE) and contains spherical particles of colloidal silica and ZrO2 dispersed in agglomerated and unagglomerated form (80% by weight, 65% by volume) embedded in a dimethacrylate resin with a ceramic/polymer ratio of 80%/20% by weight [52] and a flexural strength of 200 MPa.[53] Cerasmart (GC-Corp), Shofu Block HC (Shofu-Inc.) and Brilliant Crios (Coltene) are block resin composites with a homogeneous and uniformly distributed ceramic network, which helps to distribute stresses more effectively in all directions, the polymers offer resistance to crack propagation by preventing them from reaching a material with lower resistance to deformation (e.g., ceramic) presenting flexural strength values of up to 230 MPa.[54]

PIAR fabricated with indirect resin composites with the handmade technique use plaster models where the resin is placed in increments and light-cured for 40 seconds. Proximal contacts and anatomy can be properly performed. On the other hand, different complementary polymerization techniques such as heat, pressure, oxygen-free environments, etc. are used.

Depending on the manufacturer, PIAR are placed in an oven with temperatures ranging from 120 to 140°C after light-curing. This increases the reactivity of residual monomers and the volatilization of unreacted monomers. Similarly, other energy sources can be used for the same purpose such as dry heat, moist heat, or microwave heat, Lumamat 100. Another method to enhance polymerization is by fabricating PIAR from laboratory resins in an oxygen-free environment, due to its potential to inhibit polymerization and increase attrition rate. To do this, a nitrogen atmosphere is used to remove internal oxygen before the material polymerizes; this is the case of Premise Indirect (Kerr) and a pressurized nitrogen oven at 138°C /238°F and at a pressure of (60

psi ~ 414 kPa) where the pressurized nitrogen environment provides an inert polymerization environment while improving the density of the polymerized material.[48]

In the case of resin composite blocks, these are processed through the CAD/CAM system for PIAR fabrication. Preliminary studies on Lava Ultimate partial restorations revealed a survival rate of 85.7% after 2 years.[55]

HYBRID MATERIALS

Hybrid materials form a new group of restorative materials to be manufactured with CAD/CAM where resins and ceramics are combined taking advantage of their mechanical and esthetic properties. They are indicated for minimally invasive restorations, posterior crowns, veneers, PIAR and implant-supported crowns.

Currently, different terms such as "hybrid ceramics" or "nanoceramics" are used to refer to these types of materials; however, these can be classified according to their microstructure and mode of polymerization as polymer-infiltrated ceramic network (PICN) at high temperature/high pressure with a predominantly inorganic phase.[49,56]

The first material in this classification is VITA Enamic (VITA-Zahnfabrik) is based on a feldspathic ceramic network (86% by weight, 75% by volume) infiltrated by urethane dimethacrylate and triethylene glycol dimethacrylate polymers (14% by weight, 25% by volume).[56] Its microstructure is amorphous and both phases are mutually continuous and interconnected, with no evidence of crystallization and presents a flexural strength of 160 MPa.[57]

PIAR are manufactured by CAD/CAM system which allows to be worked in very thin thicknesses, easy to mill with high precision, does not require additional heat treatment and can be characterized to achieve better aesthetics. This group of materials is currently the first choice for this type of restorations.

Studies evaluating PICN show survival rates at 3 years were 97.4% for inlays and 95.6% for PIAR.[17]

Alongside advancements in restorative materials, adhesive protocols and CAD/CAM technologies have undergone significant improvements. When properly applied, contemporary adhesive techniques provide a strong and lasting bond between the restoration and the tooth, reinforcing the overall strength of the restored structure.[58] Furthermore, digital workflows contribute to greater accuracy in the fabrication of indirect restorations, leading to reduced clinical time and enhanced marginal adaptation.[59]

Despite these advances, gaps in the literature persist—particularly concerning the long-term clinical performance, comparative effectiveness, and cost-efficiency of various materials and techniques used in PIAR. Current evidence remains fragmented, often limited to in vitro studies or short-term clinical trials, making it difficult for clinicians to formulate comprehensive, evidence-based treatment plans.

PIAR offer a compelling alternative for the restoration of structurally compromised posterior teeth. While current materials and techniques show promising clinical outcomes, there remains much to explore in terms of long-term success, material optimization, and cost-effectiveness. As their use continues to expand in daily practice, PIAR will undoubtedly remain a focal point of research and innovation in restorative dentistry and biomaterials science.

PIAR are a conservative and predictable option for restorations of posterior teeth. The materials currently available on the market for PIAR, such as dental ceramics and resin composites, show high durability and a good clinical performance. The survival rates of these restorations are over 90% for dental ceramics and over 85% for resin composites in the first couple of years with a minimum decrease over time. Thus, the choice of the material for PIAR should always be weighed together with different factors including antagonist material, parafunctional habits, esthetics, and treatment cost.

DECLARATIONS OF AUTHORSHIP

We confirm that all authors listed in the manuscript have made contributions to its conception, design, analysis, and interpretation of data. We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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