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Evaluation of Microleakage in Direct and Indirect Composite Inlay system – A Dye penetration Study

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Abstract

Background: From past few year the use of composite inlay techniques has evolved to improve the marginal seal and adaptation of esthetic posterior restorations by greatly controlling the volume of composite resin to be simultaneously cured and bonded to tooth.

Aims and Objectives: To compare the micro leakage of direct and indirect composite inlay restorations in Class II cavities at the cervical (Gingival) margin by stereomicroscopic examination.

Materials & Methods: Forty whole extracted molars were collected & than stored in water at normal room temperature. Class II cavity preparations were prepared and restored with direct composite technique in twenty teeth and indirect inlay technique in remaining teeth. After that teeth were thermo cycled and immersed in 0.5% basic fuschin dye. Teeth were then sectioned and evaluated for dye penetration using a stereomicroscope at 16X magnification. The data was analysed using Mann-Whitney test.

Results: Direct restorative group showed maximum amount of leakage there was no statistically significant difference between the two groups.

Conclusion: By using composite inlay, adaptation and bonding of composite to dentine can be improved.

Keyword: 16X magnification, Gingival

Introduction

Currently, tooth colored posterior restorations are the first choice of the patients. However, micro leakage is one of the major concerns associated with composite resins especially in the Class II cervical margins. Cervical micro leakage contributes to high incidence of secondary caries and accounts for clinically failed restoration.[1]

Polymerization shrinkage remains one of the main shortcomings of resin composites. Composite when placed in a large cavity, the mass to be polymerized is so large that the shrinkage forces win out, producing marginal defects and gaps, despite careful application and use of adhesive techniques. Reducing the in situ cured composite mass is one of the most effective adaptation-enhancing factors.[2]

Adequate polymerization of resin composite is considered to be a very important factor for assuring appropriate physical and biological properties. Shrinkage stress, however, is one of the in herentdis advantages that occur when visible light-activated resin composites are submitted to lightpolymerization.[2] stresses arising from post-gel polymerization shrinkage may produce defects in the composite to tooth bond, leading to failure associated with microleakage, postoperative sensitivity, and recurrent caries. These problems are the most frequent consequence of fluid penetrating along cavity walls toward the pulp. Soft-start polymerization with short-pulses of light energy in association with glass Ionomer as the gingival increment, and incremental techniques have been used in an endeavor to minimize this effect.[3]

Different resin-composite inlay systems were also developed and direct composite resin is one of the most popular. However, because of the complexities associated with insertion and finishing techniques in large direct composite restorations, many clinicians have difficulty in establishing proper anatomic form, proximal contour and contact. Indirect inlay systems became popular to overcome this limitation of direct restorations. Shrinkage stress should be minimized with indirect restoration, since polymerization occurs before the restoration is cemented. However, indirect resin restorations require internal adjustment, which could result in poor marginal fit.[3]

The growing demand for more esthetic restorations has led to increased popularity of resin composite restorations in posterior teeth. The recently developed resin composites are superior to the earlier versions in regard to wear resistance and color stability, but the main shortcoming of the composites, i.e. the polymerization shrinkage of the resin still remains. In posterior cavities, especially with the cervical margin situated in dentin, the mass to be polymerized is so large that the shrinkage forces win out, producing marginal defects and gaps despite careful application. This facilitates microleakage, which can cause secondary caries, pulpal irritation, postoperative sensitivity and marginal discoloration.[4] The use of composite inlay techniques has proved to be an elegant approach to improve the marginal seal and adaptation of esthetic posterior restorations by greatly restricting the volume of composite resin to be simultaneously cured and bonded to tooth. A composite inlay restoration is cured by secondary application of heat or light outside the mouth and cemented into the prepared cavity. It may be completed by two techniques; first is direct technique i.e. chair-side procedure. The second is an indirect technique in which composite inlay is fabricated on a stone die. 8

The above concerns regarding disadvantages of metallic restorations and disadvantages of direct composite restorations, Indirect tooth colored restorations especially composite inlays have come to occupy a vital place in the treatment choices presently available. Even though tremendous improvements have taken place in material science of resin composites research is lacking in terms of the best available option to choose between direct fabrication of composite inlay over the tooth or to fabricate the composite inlay outside the mouth over the cast prepared by making impression of the tooth preparation.

Thus, the purpose of the present study is to evaluate the degree and extent of microleakage of directly fabricated and indirectly fabricated composite inlays at the crucial gingival wall of the preparation by means of a stereomicroscope

Method

Forty mandibular molars, which were extracted for periodontal reasons, free of restorations and caries were selected. Teeth were stored in water at room temperature until use. Conservative Class II mesio-occlusal inlay cavities were prepared using tapered fissure carbide bur (No.271) in a turbine handpiece with water spray coolant. The complete preparation had a minimal occlusal depth of approximately 1.5 mm. The cavity walls diverged towards the occlusal surface. The other dimensions of the cavities were, axial depth of 2 mm, proximo-facio-lingual width of 3 mm at the gingival and 4 mm at the occlusal. The gingival cavosurface margins were situated 1mm occlusal to CEJ. The cavosurface margins were finished to butt-joint. After completion of the preparations, the teeth were thoroughly rinsed with water to remove debris and dried with air.

The teeth were assigned randomly into two groups of twenty each.i.e.

Group I – Direct composite inlay restoration.

Group II – Indirect composite inlay.

Direct inlay

Following cavity preparation and application of separating medium, oblique incremental packing of composite resin and polymerization techniques were employed. Each of the layers inserted into the prepared cavities were initially cured from a gingival direction (40 seconds) and then from occlusal direction (40 seconds). The composite inlay was removed from the tooth and post curing was carried out for 104^0 C for 6 minutes in an inlay curing oven.

Cementation procedure was initiated with etching of cavity walls, 37% phosphoric acid was applied on enamel for 15 seconds and after 15 seconds the etchant was applied on dentin, for a total etching time of 30 seconds for enamel and 15 seconds for dentin. Dentin bonding agent was applied according to manufacturer's instructions. The inner surface of the composite inlays was treated with 37% phosphoric acid for 60 seconds, rinsed with a pressure jet and was air dried. The inner surfaces were then coated with silane coupling agent, dried for 60 seconds and a dentin bonding agent was applied. Vario link (Ivoclar) was applied to the cavity walls. The composite inlays were pressed into the cavity for 4 minutes. The composite inlay was cured for 40 seconds on each surface. Finishing was done with a super-fine finishing diamond point. All restorations were finished with discs 24 hours after cementation.

Indirect inlay

Impression of the preparations was taken using a putty wash system. Impressions were poured with die-stone. Separating agent was applied to the cavities of the stone dye. The composite resin was placed in oblique increments and cured from gingival direction (40 seconds) and then from occlusal direction (40 seconds). Further post-curing of inlay was carried out for 104^0 C for 6 minutes in an inlay-curing oven.

The inner surface of the composite inlays was treated with 37% phosphoric acid for 60 seconds, rinsed with a pressure jet and air dried. The inner surface is then coated with silane coupling agent, dried for 60 seconds and a dentin bonding agent was applied. For itching of cavity walls, 37% phosphoric acid was applied on enamel for 15 seconds and after 15 seconds the etchant was applied on dentin, for a total etching time of 30 seconds for enamel and 15 seconds for dentin. Dentin bonding agent was applied according to manufacturer's instructions. Dual cure resin luting cement was applied to the cavity walls. The composite inlays were pressed into the cavity for 4 minutes. The cemented composite inlay was cured for 40 seconds on each surface. Finishing was done with a super-fine finishing diamond point. All restorations were finished with discs, 24 hours after cementation.

Thermo cycling procedure

All the specimens were stored in water at 32°C for 24 h before being thermocycled. The teeth in the five test groups were thermocycled 1500 times between 5 and 55°C with a dwell time of 15sec. After the thermo cycling, the teeth were stored in water at 32°C for another 120h before the microleakage staining procedure.

Microleakage staining and analyzing procedure

Each tooth was removed from the water and dried carefully in a stream of compressed air. The apex was sealed with sticky wax, and the entire tooth was coated twice with nail varnish, apart from a 1-mm-wide zone adjacent to the margins of the composite restoration/iniay. The teeth were immediately transferred to a 2% aqueous solution of methylene blue, in which they were stored at 32°C for 24 h. The methylene blue storage was followed by a short rinse in water. The roots were cut off 2-3 mm apically from the cervical border of the restoration/inlay and embedded in a casting resin (Castolite Resin, Buehler Ltd, Lake Bluff, Ill , USA). Using a slowly rotating diamond saw (Isomet, Buehler Ltd) with kerosene (J T Baker Chemicals BV, Deventer, Holland) as the lubricant, the teeth were sectioned mesiodistally through their long axis.

The sectioning resulted in two approximately equal parts, which were both analyzed for microleakage. The sections were coded and were analyzed under a stereomicroscope (Stereo Microscope No 7, Bauscher , Rochester, N.Y., USA) at X50. Each section was photographed and the degree of microleakage was evaluated in accordance with Table 2. Differences in leakage scores between the various groups were compared using the Wilcoxon rank sum test. The level of significance was set at $p < 0.05$.

Score 0 - No dye Penetration.

Score 1 - Dye penetration upto 1/3 of the length of gingival wall.

Score 2 - Dye penetration from 1/3 to 2/3 of the length of gingival wall.

Score 3 - Penetration greater than 2/3 the length of gingival wall but not including the axial wall.

Score 4 - Dye penetration with penetration spreading along the axial wall.

The grading were then tabulated and are statistically analyzed using Mann – Whitney test with P values less than 0.05 were taken to be statistically significant.

Method

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Fig. 1: Sectioned teeth after Dye penetration for 24 hrs.

Result

Score	Direct Inlay	Indirect Inlay
0	10 (50%)	12(60%)
1	5(25%)	4(20%)
2	2(10%)	2(10%)
3	2(10%)	1(5%)
4	1(5%)	1(5%)

of 20 total samples in each group, 10 (50%) samples in direct and 12(60%) samples indirect inlay group showed 0 score. 5 (25%) direct 4 (20%) indirect inlay score 1, 2 (10%) each group showed score 3 and direct and 1 (5%) and 1 (5%) direct and 1 (5%) showed score 4

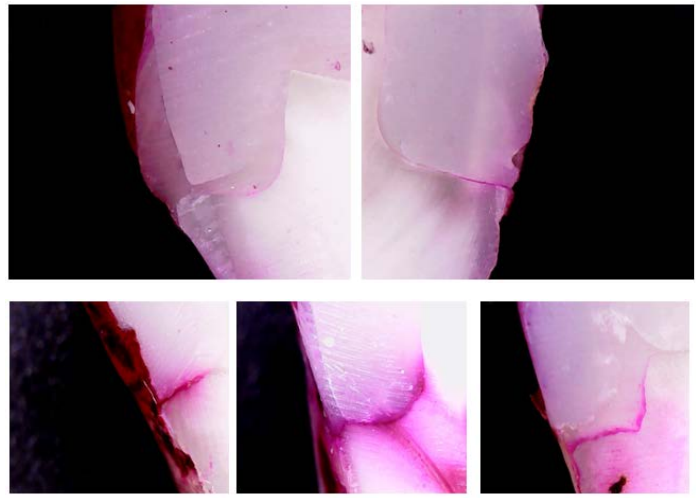

Fig. 2: Apex sealed with green compound

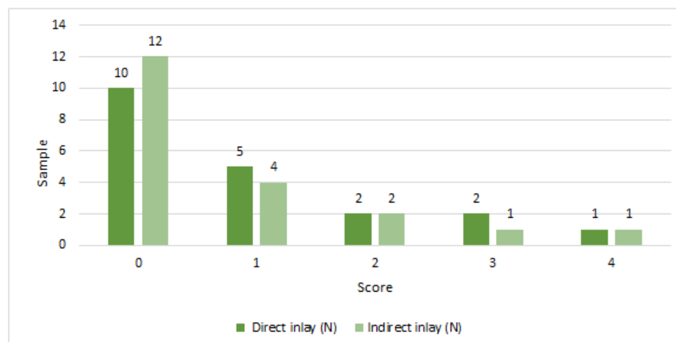

Figure1: Sample distribution of direct and indirect inlay score

Figure 1: represents that 20 sample each group with score, 10 and 12 sample obtained 0 score. Whereas, 1 sample each group obtained 4 score.

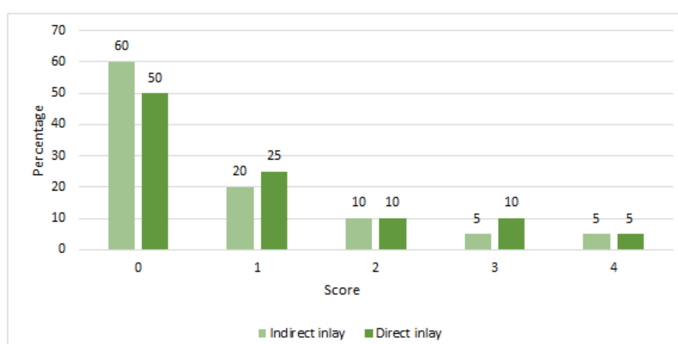

Figure 2: Percentage distribution of indirect inlay and direct inlay score.

Figure 2: represents that percentage distribution of indirect and direct inlay. (60%) indirect group and (50%) samples in direct inlay group showed 0 score, (20%) indirect group and (25%) indirect inlay group showed 1 score, (10%) each group showed 2 score, (5%) indirect group and (10%) indirect inlay group showed 3 score and (5%) each group showed 4 score.

Table 1: T test association between direct and indirect inlay

Variable	N	Mean	Std. Err	SD	[95% Conf. Interval]		P-value
Direct Inlay	20	0.95	0.28	1.23	0.37	1.53	0.422
Indirect Inlay	20	0.75	0.26	1.16	0.21	1.29	

Table 1: represents that means and standard deviation two group showed 0.95±1.23 and 0.26±1.16 of direct and indirect inlay respectively. The mean scores obtained were not statistically significant (p 0.422)

Table 2: Mann Whitney test association between direct and indirect inlay

group	N	sum of score	Mean score	P-value
Direct Inlay	20	430.5	21.525	0.54
Indirect Inlay	20	389.5	19.475	

Mann Whitney test

Discussion

For many years the dental profession hasstrived to achieve good adhesion of resin composites to tooth substrates, since reliable bonding should produce less microleakage and more restoration stability. In accordance with Hannig, Friedrichs (2001), a central goal achieved by adhesive dentistry has been to secure intimate adaptation between the restorative materials and the cavity walls in order to resist microleakage. The occurrence of a gap could promote dentinal fluid percolation, and this phenomenon may cause pulpal sensitivity during functional load on the restoration, in addition to intensifying microleakageand bacterial invasion whenever the marginal integrity of the restorations fails.[1]

Marginal adaptation of restorative materials is a matter of key concern in dentistry. Direct posterior composite restorations have a disadvantage of not completely polymerizing and adequately sealing the relatively inaccessible gingival wall. At this site the enamel wall is thin, lacks regular prismatic configuration or is entirely missing and micro leakage is prevalent in this area. Two major factors that determine for marginal gaps to develop are polymerization shrinkage and competing composite tooth adhesive bond.[8]

One of the major advantages of inlay technique is that polymerization shrinkage can be controlled and hence better marginal shrinkage can be expected than direct restorations. With the use of inlay technique higher degree of cross-linking and stress relaxation can be obtained, since the application of light and heat may initiate new centers of polymerization. Another advantage is that the inlay can be finished outside the mouth, hence inadequate contact areas can be improved before cementation. Stresses placed on the tooth and the resin bond is reduced since the polymerization shrinkage occurs outside the mouth. Therefore, micro leakage, post-operative sensitivity and secondary caries will be reduced. Micro leakage has been a major concern in restorative dentistry and is used as a measure by which clinicians and researchers can predict the performance of restorative materials in oral environment. Kidd has defined micro leakage as clinically undetectable passage of bacteria, fluids, molecules or ions between the cavity wall and the applied restorative material.[8]

Several techniques have been devised to test the micro leakage of restorations in vitro. In vitro studies include the use of stains, radioactive isotopes, air pressure, bacteria, neutron activation analysis, scanning electron microscopy, artificial caries technique, autoradiography and elective conductivity. According to Myers margins of restoration possess dynamic micro crevices that contain a busy traffic of ions and molecules. In this study micro leakage at the gingival margin of direct composite inlays and indirect inlay restorations was evaluated using dye penetration study. The gingival margin was placed in enamel and no bevels were placed during the cavity preparation. D.Dietschi showed that composite inlays proved to be superior with respect to marginal seal and adaptation quality when butt preparations were used. The polymerization shrinkage in the composite inlay techniques is limited to the luting cement layer.[8]

Since adhesive inlays are inserted into the cavities with resin cement, the luting gap is always susceptible to increased wear as the resin cement is less wear resistant than the post-cured composite inlays. When the interface of luting cement is covered with a glycerin gel, oxygen inhibition during polymerization is prevented. Another beneficial effect is in the prevention of excessive early wear of the luting resin composites. Better marginal adaptation and improved wear resistance have been reported.[8]

The results obtained in present study showed no statistically significant difference for micro leakage between the two groups. The leakage seen in inlay group could be attributed to shrinkage stresses from the composite cement, air bubbles incorporated at the interface or incomplete bonding. Long-term clinical evaluations are needed to further evaluate the efficiency of this restorative technique.[8]

The use of composite inlay techniques has proved to be an elegant approach to improve the marginal seal and adaptation of esthetic posterior restorations by greatly restricting the volume of composite resin to be simultaneously cured and bonded to tooth.[8]Composite resin, serves as esthetic alternative to amalgam and cast restorations. Posterior teeth can be restoredusing direct or indirect composite restorations. The selection between direct and indirect technique is a clinically challenging decision-making process. Most important influencing factor is the amount of remaining tooth substance.[14]

Increase in demand for esthetics has led to the development of tooth-colored, nonmetallic restorations such as direct composite restorations, indirect composite inlays, and ceramic inlays or onlays.[14]Aesthetic dentistry continues to evolve through innovations in bonding agents, restorative materials, and conservative preparation techniques. The use of direct composite restoration in posterior teeth is limited to relatively small cavities due to polymerization stresses. Indirect composites offer an esthetic alternative to ceramics for posterior teeth.[15]

Dental composite formulations have been continuously evolving ever since Bis-GMA was introduced to dentistry by Bowen in 1962. Recent developments in material science technology have considerably improved the physical properties of resin-based composites and expanded the irclinical applications. Dental restorative composite materials can be divided into direct and indirect resin composites (IRC). IRCs are also referred to as prosthetic composites or laboratory composites. These materials offer an esthetic alternative for large posterior restorations. Touati and Mörmann introduced the first generation of IRCs for posterior inlays and on lays in the 1980s.[15]

If we talk about longevity, prospective clinical studies on posterior composite resin restorations show an annual failure rate of oneto four percent, depending on the type of study and the materials selected.[16]

A 17-year study of ultraviolet-cured posterior composites by Wilder and others demonstrated an excellent success rate of 76%.Hodge found that the overall failure rate of the composite restorations in posterior teeth at eight years was 13.7% (16.4% for the microfilmed composite; 15.4%for a fine particle hybrid composite; 9.3% for a relatively coarse particle hybrid composite). Raskin found actual 10-year failure rate to have been between 40 and 50%. Cumulative approximal and related occlusal wear, with the resultant loss of contact areas, was found to be an important cause of failure, 10 years after placement.[16]

The present ADA guidelines require an 18-monthperiod of clinical service for acceptance of a new all-purpose composite resin. It might be better to have an evaluation period of at least five years before coming to any conclusions. Opdam and colleagues, in a longitudinal study of over 700 posterior composite restorations placed by dental students, reported a 5-year survival rate of 87%, with an annual failure rate of 2.8%. They concluded that dental students are able to place resin composite restorations in posterior teeth, with an accept able mean annual failure rate.[16]

Dijken, in a 11-year evaluation of direct inlays and on lays, found good durability for the direct resin composite inlay/onlay technique. Excellent marginal adaptation and low frequency of secondary caries inpatients with high caries risk were shown. No apparent improvement of mechanical properties was obtained by the secondary heat treatment of the inlays. Also, the difference in failure rate between the resin composite direct technique and the inlay technique was not large indicating that the more time-consuming and expensive inlay technique may not be justified.[16]

The search for an ideal esthetic material for restoring teeth has resulted in significant improvements in both the material aspect and the techniques for using them. Resin composites harden through a process of free radical polymerization of the methacrylate groups, which leads to a decrease in volume, causing polymerization shrinkage that may vary from 1% to 5%.In the past, various techniques have been recommended to minimize the effects of polymerization shrinkage. They include incremental placement the “guided shrinkage” technique; soft-start polymerization and pulse delay techniques’ use of low modulus lining materials, such as glass ionomers resinous liners; new-generation dentin bond in agents and megafillers.[17]

Considering these limitations, the concept of the heat-treated composite inlay/on lay was developed by Wendt in 1987. Wendt demonstrated in his *in vitro*studies that heat treating at 250°F for seven to eightminutes substantially improved hardness and wear resistance of the resins. Since then, post-cure units have evolved. Recent post-cure units use an additional light source, along with heat and pressure for post curingthe resin composites.[17]

Single appointment direct posterior resin bonded composite(RBC) restorations should ideally be restricted to small-to-medium-size intracranial lesions (ADA, 1998).This assumption is based on the poor wear characteristics and marginal behavior of early RBC (Roulet, 1997).The high wear rate of original direct RBC caused a loss of anatomic shape and led to the exposure of cavity margins moreover, marginal breakdown and marked technical sensitivity resulted in compromised RBC restorations especially in the molar region. Short-term clinical evidence has shown no or low failure for direct inlay/onlays (Wendt Jr &Leinfelder, 1992; Krejci, Guntert & Lutz, 1994; van Dijken, 1994).However, Wassell, Walls and McCabe (1995) have reported a greater number of episodes of post-operative sensitivity and a trend towards higher failure rates for direct inlays. The same findings were reported by other authors (Pallesen & Qvist, 2003). This data is influenced by the use of inferior adhesive systems; however, notable is the lower post-operatory sensitivity recorded for direct RBC.[21]

Indirect laboratory processed composites have gained increased popularity over the last decade. In theattempt to improve the wear resistance of resin composites, heat, pressure and a nitrogen atmospheric treatment may be combined to form a relatively voidfree,well-polymerized resin matrix. However, the basic chemistry of indirect RBCs remain very similar todirect materials; differences in mechanical properties are minimal and are not expected to be clinically significant(Swift, 2001). Mandikos and others (2001) reportedno improvement in second-generation indirect RBCs(Artglass, belleGlass, Sculpture, Targis) mechanical properties when compared to a first-generation indirectRBC (Concept).[21]

Thordrup, Isidor and Horsted-Bindslev (2001) reported no significant difference in survival between direct and indirect resin composite and ceramic inlays after five years of clinical service; although the survival rate of the different types of inlay was considered acceptable, itwas comparable to the survival rate of direct RBC fillings reported in controlled clinical studies (Rasmussen& Lundin, 1995; Barnes & others, 1991). The authors questioned the cost benefits of indirect restorations as being superior to direct RBC restorations. A recent literature review reported no significant difference in the longitudinal clinical behavior of posterior direct and indirect resin composite restorations over a three-yearevaluation period (Hickel & Manhart, 2001).[21] However, in direct composite resin restorations, the most important problems were various fractures, wear and loss of themarginal seal leading to pulpal irritation, postoperativesensitivity, marginal staining, and secondary caries.Also, other problems related to composite resins wereinsufficient interproximal and occlusal morphology due to difficult clinical handling procedures.Indirect laboratory-processed composite systemspresent an esthetic alternative for intracranial posterior restorations and provide esthetic results that may alsoreinforce tooth structure. Additional clinical benefits include exact marginal integrity; wear resistance similar to enamel, wear compatibility with opposing natural dentition, optimal esthetics, ideal proximal contacts, and excellent anatomic morphology.[23]

The indirect composite resin restoration is an attempt to overcome the main disadvantage of polymerization shrinkage of the direct composite resin restorations. The secondary polymerization of the composite inlay, at a high temperature, improved the degree of conversion and allowed the initial polymerization shrinkage and the following post-cure stress to occur before insertion. In addition, postoperative sensitivity is decreased in composite inlays compared to direct composite fillings.[23]Touati in France 1983 and James in USA 1983, were the first to propose the first to offer moulded composite incrustations, made from an impression, and secondarily bonded in the mouth. These incrustations were what everyone agreed to name: composite inlays. Composite On lay/Inlays turned out to be an interesting restoration option among other possible choices in our therapeutic arsenal.[25]

The advantages procured by the use of indirect restorations:

a) Minimize the effects of polymerization shrinkage and reduce its stress effects on cavity walls.

b) Polymerizing the composite as a whole, eliminating the risk of remaining free monomers.

c) Better marginal adaptation, better sealing and reducing the risk of hiatus.

d) Better occlusion reports and proximal contacts.

e) Better aesthetic integration

f) And most important point, best mechanical properties during thermal and photonic treatment in the laboratory.[25]

Nevertheless, they show many limits such as:

a) The relatively high cost compared to amalgam and composites by direct method.

b) Multiple sessions are needed.

c) In addition, and like all bonding treatments, it is a technique that interesting patients with good oral hygiene and good motivation.[25]

The stratification build-up associated to the large choice of composites currently available, allow us to have the same aesthetic properties of the direct and indirect composites. The mechanical properties of indirect inlays are certainly more interesting compared to direct composites, thanks to heat treatments and post polymerization. In addition, the indirect composite inlay offers better control of cervical tightness and better restitution of the contact point in cases of proximal loss of substance. The cost is certainly lower when the restoration is carried out directly in the mouth. As for longevity, clinical studies have shown that there is no significant difference between direct and indirect method inlay.[25]

The main causes of failure are secondary caries, fractures, marginal defects, wear and postoperative sensitivities. A study conducted by the Lafarge's et al. shows that the failures are not related to the material, but a large part is due to the implementation and the respect of the operating stages. The choice for the direct or indirect method is mainly guided by the clinical situation.[25]

Talking about direct-indirect composite technique, composite is applied to a no retentive tooth preparation (e.g., a non-carious cervical lesion or a veneer/inlay/on lay preparation) without any bonding agent, sculpted to a primary anatomic form, and light-cured. The partially polymerized restoration is then removed from the preparation and finished and tempered extra orally chair side. The finished inlay isbonded to the preparation using a resin-based luting agent. Advantages of this technique include enhanced physical and mechanical properties afforded by the extra oral chair side tempering process because of increased monomer conversion, and greater operator control over the final marginal adaptation, surface finishing and polishing, and anatomy of the restoration, given that these elements are defined outside of the patient's mouth. The direct-indirect approach also affords enhanced gingival health and patient comfort. Although the direct-indirect composite technique is not new, recent advances in materials, instrumentation, and chair side light-curing have generated renewed interest in this restorative approach given its advantages over directly placed composites.[26]

Summary of clinical studies on IRC.

Clinical study type	Materials compared	Parameters compared	Comments
Four – six year follow up of resin inlay /onlay (Leirskar *et al.* 2003)	Tetric, Maxxim, Z 100	Form, MF,MD, CM,SR,SC	22% of restorations - acceptable and required minimal corrections. 2- surface restoration performed better than 3 surfaced and onlays
Seven year follow up resin inlay / onlay (Donly *et al.* 1999)	Cast gold, Concept	F, CM, MD, SC, W, SR, (Ryge criteria) in molars and premolars	50- 75% Alpha ratings for all parameters for concept. Concept yields clinically acceptable restorations particularly in premolars
One year follow up (Cetin AR *et al.* 2009)	AELITE, Filtek supreme XT, Tetricevoceram (Nano filled direct composites) Tescera ATL, estenia	Class I and Class II SR, CM, MD,PS,GA, Rt (Ryge criteria)	85- 100% Alpha ratings for all parameters for both direct and indirect composites.
Three year follow up[88] (Ducik w *et al.* 2010)	Admira (ormocer), Grandio	SR, F, MI,MD (Modified USPHS criteria)	Alpha 1 score for overall success -71% - both materials Both materials have acceptable success after 36 months
Three yr follow up of CAD CAM composite and ceramic[89] (Vanoorbeek *et al.* 2010)		marginal fit, periodontal parameters, volume loss, and wear patterns of the veneering material	Survival rate andsuccess rate was 88 and 56% forcomposite Survival rate andsuccess rate was 97 and 81% for ceramics Increased wear and decreased esthetics of composite makes ceramics superior for CAD CAM restorations
One year results for direct and indirect composite inlays[90] (Mendonca *et al.* 2010)	TetricEvo Ceram, Targis	modified USPHS criteria forCM, MD, SC, AF, SR, MI, PS.	This is a short term study. CS, PS – no changes CM, AF, SR similar to both materials. Other parameters direct resin performed better.
A 4-6 yr retrospective study on cracked tooth bonded with indirect resin[91] (Signore *et al.* 2007)	Direct composite restoration followed by indirect onlay		Acceptable &survival rate-93 % 7% failure rate
A 3 yr RCT in evaluating direct and indirect composite for severely worn teeth[92] (Bartlett 2007)	32 direct and indirect restorations in premolar and molar of severely worn teeth.	Wear fracture and loss of material was evaluated	22% fractured, 28% - complete loss of restoration. Direct and indirect resin composites for restoring worn posterior teeth is contraindicated.
10 year follow up on direct, indirect and ceramic inlay[93] (Thordruo 2006)	Cerec Cos 2, Vita Dur, Brilliant DI, Estilux	modified retrospective study on cracked tooth bonded with indirect resin (Signore et.al 2007California Dental Association Quality Evaluation System SR, F,SC	3 estilux inlays were replaced 6 vitadur inlays were repaired Both materials were in acceptable range after 10 yrs.
5 yr follow up of direct inlays and conventional resin restorations[94] (Wassell *et al.* 2002)		MD, MF, SR,W (USPHS criteria)	More failure of inlays than conventional composites Direct inlay technique gave no clinical advantage over conventional, incremental placement
Composite resin fillings and inlays. An 11-year evaluation[95] (Pallesen *et al.* 2003).	Brillinat DI, Estilux, SR isosit	Class II restoration in molar and premolars (USPHS criteria)	70% of direct fillings and 88% of inlays were in acceptable ratings Failure more in molar than premolar failure were fracture of restoration, secondary caries, fracture of tooth, loss of proximal contact, and loss of restoration no significant difference between fillings and inlays or between types of restoration
Three year follow up of resin inlays[96] (Manhart *et al.* 2010)	Artglass, Charisma	Class I, single and multi surface Class II inlays. (USPHS criteria)	89.8% of Artglass and 84.1% of Charisma inlays – acceptable No significant differences between premolar and molars Small inlays survived better Failure was mainly due to bulk fracture, loss of marginal integrity.
Two year wear assessment[97] (Stober *et al.* 2008)	Artglass	Influence of gender, arch, and crown location on the occlusal wear	In 1 yr – 19μ for anterior and premolar, 21μ for molars In 2 yr – 36 μ for anterior, 44μ for premolar and 84μ for molars.
Adhesively luted metal free crowns for5 years[98] (Lehmann *et al.* 2009)	Artglass	Location and preparation design on survival rates. 68 posterior, 46 anterior crowns with 0.5mm shoulder / 0.5mm chamfer was prepared	13 crowns – replaced, 5 crowns – repaired. No difference between location or preparation design on complications. survival rate -96% in 3 yrs 88.5% in 5 yrs can be used as long term temporary crown increased plaque accumulation restricts the indication

MD- marginal discoloration, SC – secondary caries, SR- surface roughness, MF- marginal fit,W-wear, CM- color match, F- form, MI-marginal integrity.

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