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Systematic review :

Long-term clinical performance of partial coverage restoration (inlay or onlay): A systematic review of in vivo studies

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Abstract

Purpose: to evaluate the survival rate of indirect bonded partial restorations (IBPR), inlays onlays types, by the analysis of the success and failure factors, the risks and the benefits of these restorations through a systematic review based on in vivo studies.

Materials and Methods: a systematic literature review was performed on MEDLINE, via Pubmed interface using Mesh terms and Boolean equations to identify the clinical trial articles dealing with inlays and onlays published from 2003 to2022.After articles selection, data were extracted and analyzed by independent authors according to a predefined reading grid. **Results:** Twenty two final international articles were selected according to the inclusion and exclusion criteria, based on in vivo studies concerning the survival rate and the main failure factors of inlays onlays.

Conclusion: In view of this study, data analysis of the retained articles has allowed to show the reliability of IBPR presenting an important survival rate (higher than 90%). Failures exist but their causes are well-identified. A good knowledge of the indications, the materials properties and the preparation and bonding rules are the parameters to be mastered for the success of these restorations.

Key words:inlays onlays; ceramics; composite; in vivo clinical studies; systematic literature review.

Introduction:

Since the late 2000's,the progress witnessed in the field of adhesive dentistry as well as the actual tendencies towards the respect of the principle of tissue economy has allowed the use of more and more conservative treatments.

Preservation of maximum residual healthy dental tissues has nowadays become the priority in the treatment of substance loss both for anterior and posterior teeth.

* The indications of IBPR ,inlays onlays type, in the posterior sector are actually based only on in vitro studies .But what about their clinical performances and longevity?

* What are the conclusions of the in vivo studies?

Through this article, we aimed to conduct an analysis of the international scientific literature based on in vivo studies in relation to the use of inlays onlays .We later confronted these restorations to their real conditions for more or less long periods .We ended by identifying the failure causes, the risks and the benefits of these restorations.

Materials and methods:

Search strategy:

PICOS question:(Population (P), Intervention (I), Comparison (C), Outcomes and Study Design (O), Study type (S)) defined the search strategy, where:

P = Patients who had received resin or ceramic inlays and onlays;

I = Inlays and onlays that were made of resin or ceramic;

C = Resin inlays, onlays versus Ceramic inlays, onlays;

O = Survival rate;

S = Randomized controlled clinical trials (RCT) as well as clinical follow-up studies.

A systematic review was performed on Medline, via Pubmed interface using the following **Mesh words**(medical subject Healing) and their combinations "inlays","onlays", "ceramics", "composite resins", "clinical studies". Some Boolean equations were formulated by using the Boolean operator "AND".

The articles responding to the following inclusion criteria were retained : Articles published in the English Language ,clinical trials articles ,whose full text is accessible and published during the period extending from 2003 to 2022.

In the majority of the studies retained , **USPHS(**United States Public Health Services) and **CDA**(California Dental Association) were the criteria used in the evaluation of the clinical performances of these restorations. These criteria allow the evaluation of the degree of excellence or conformity to the standards.

The CDA method includes two principle assessments,either "satisfactory"(AorB) or "non acceptable" (CorD) ,knowing that "A":conforms to standards/"B":to be reassessed/"C":to be preventively replaced/"D":to be immediately replaced.

In each category, the surface condition, the shade ,the anatomic shape and the marginal integrity (to which other subcriteria such as occlusal contour or discoloration are added) are taken into account to evaluate the longevity of the restorations.

The USPHS method uses four scores:

"Alpha": if the restoration does not require any modification and it is clinically unchangeable.

"Bravo" in case of presence of a minor defect without periodontal problems, secondary carious lesion, irreversible pulpitis, minor discoloration changes :not requiring intervention or minor repair.

"Charlie": a defect altering the dental structure, the periodontal tissue or the inlay onlay structure :requiring a repair of the restoration.

"Delta": a defect altering the tooth structure ,the periodontal tissue or the inlay onlay structure: requiring replacement of the restoration.

RESULTS

Study selection:

The search strategies employed yielded 1604 studies [figure 1]. After the titles and abstracts were evaluated and duplicates were eliminated, 329 articles were identified; after title and abstract revision 307 of these were excluded.

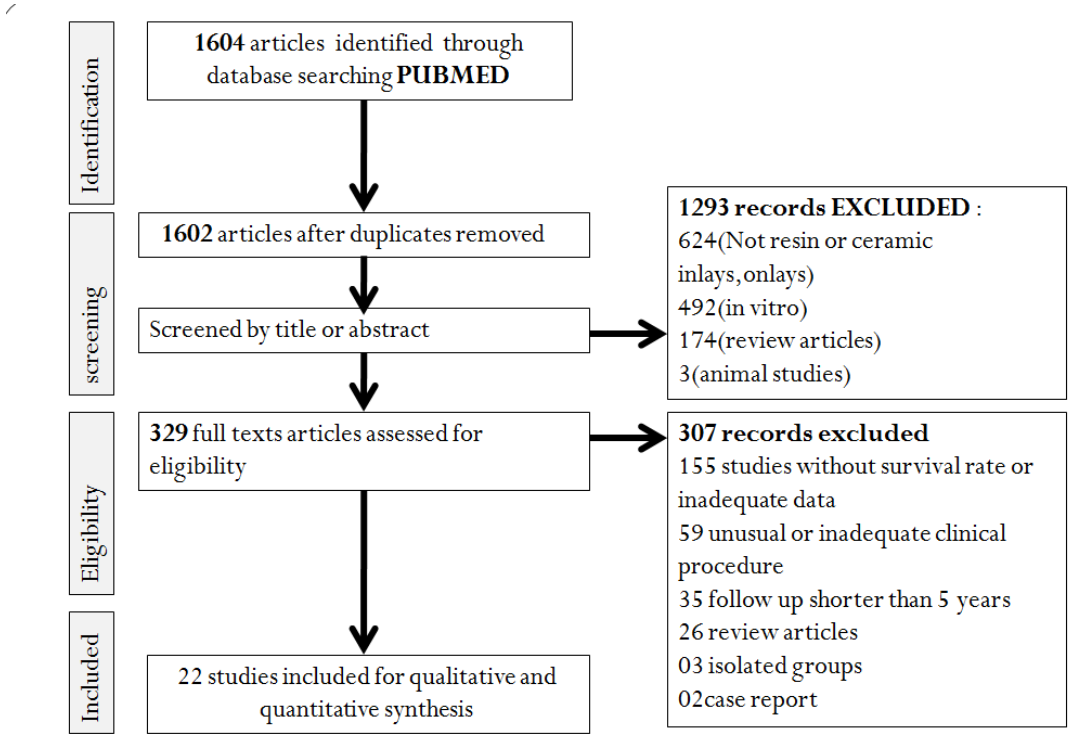

Figure 1 :Screening process flowchart

* Finally, Twenty two international articles published between 2002 and 2022 were therefore selected, based either on in vivo studies or on literature review concerning the survival rate and the main failure factors of inlays onlays in ceramics and /or composite resin.

The relevant data in these articles are presented in table I,II and III considering the materials used ,the bonding materials, the study duration and the number of restorations performed.

* Table I:(7articles):concerning only inlays onlays in composite resin.

* Table II(14articles):dealing with the use of restorations in ceramics.

* Table III(1article):concerns a study comparing inlay onlays in composite resin and in ceramics

Discussion

* In this work, the systematic review has used more than three Boolean formulas in order to guarantee a maximum of in vivo clinical studies dealing with the longevity and the failure factors of IBPR, inlays onlays type. The search was performed on Medline database via Pubmed interface.

* In this review ,all the studies agree that IBPR show a survival rate higher than 90% within 10 years and a mean annual failure rate between 2.1 and 20% for the restorations in composite resin and between 0 and 16% for the restorations in ceramics.

* According to the High Authority of Health (HAH), clinical failure is defined by, at least, one of the following situations:

-Either in case of a fractured,debonded or replaced inlay onlay:in this case ,we attribute a score C or D to the restoration according to CDA or a score Charlie or Delta according to USHPS.

-Or in case of an abutment tooth requiring an endodontic treatment (hypersensitivity) or a new prosthetic restoration(following tooth fracture)

* Through the entire studies analyzed ,we noticed that the authors succeeded to highlight the main failure causes of IBPR as well as their onset frequency.

*** The first cause: "Fracture":**

It represents the major enemy to IBPR in cosmetic material and more particularly in ceramics.

This fracture can occur within the material itself indicating an occlusal overload or a defect in the preparation that does not allow enough prosthetic space. This phenomenon can also be explained by a too narrow isthmus or an unrounded angle within the preparation .

It is worth nothing that treatment of such fractures differs according the material of restoration used. In fact, unike ceramics which necessarily requires its removal in case of fracture ,resin repair remains possible even if it negatively affects its mechanical properties.

The fracture can also occur within the **dental tissue**. This can be explained by **a defect in the preparation** ,a bad evaluation of the residual tissue resistance ,or a defect of the occlusion adjustment .To treat this problem, **cusp coverage** may be used in case of deep restoration.

*** Second cause: "Hypersensitivity":**

It can appear during the first weeks following bonding.

Pulp proximity often occurs following the preparation criteria as well as the carious lesion extent. Moreover, because of the materials used during the bonding protocol, the pulp is more aggressed and an inflammatory reaction process can be initiated ,sometimes reaching the condition of irreversible **pulpitis**. To prevent this problem, the use of an **immediate dentin sealing** during the temporization phase allows not only to the limit the risk of postoperative hypersensitivity but also to reduce the risk of bacterial contamination and to increase the quality of adherence after bonding. Thus, the use of a self -etching adhesive seems to be preferable given its low aggressiveness towards the pulp.

Third cause: "Secondary caries":

* It is a rare factor. In fact, in most studies, no secondary caries was detected. They generally occur following **a loss of marginal integrity**.

* In all the studies analyzed, the marginal adaptation defect appeared in the majority of the restorations whatever is the nature of the bonding materials or the restoration. However, it seems that this problem is less frequent in case of ceramic restorations and when we use a resin cement with etch and rinse adhesives.

The loss of marginal integrity is clinically reported by **marginal discoloration**. Several hypotheses allow to explain this phenomenon:

-A lack of bonding to the enamel
-A dissolution of the resin matrix of the bonding agent in oral fluids due to the bonding material fatigue.
-A bad polymerization of the bonding material

Through these studies, the authors studied a set of factors and parameters that could affect the survival rate and the longevity of IBPR. Among them, we can cite :

*The choice of the restorative material: All the authors agree that the materials used in IBPR should present sufficient mechanical resistance to be able to support the **masticatory forces** while being compatible with the bonding procedures

** **Composite resin:** Its weak elasticity resembling that of the dental tissue allows it to play the role of a shock absorber. However, under the effect of the high occlusal forces ,resin undergoes a deformation and consequently transmits more constraints to the dental structure. This phenomenon may be at the origin of dental fracture.

We therefore note the benefits of nanoceramic resins(e.g. LAVA TM Ultimate proposed by M ESPE) requiring the use of the CAD-CAM technique and offering better mechanical properties

**** Glass ceramics:** It represents the material of choice given its mechanical resistance ,its biomimetics and its biocompatibility .The restoration is therefore performed either by the CAD-CAM technique or the pressed ceramics technique

Thanks to its rigidity ,glass ceramics undergoes little deformation under the effect of the occlusal forces and it therefore tends to reinforce the tooth-restoration entity. However, it is

exposed to a higher risk of fracture. It is therefore beneficial to reinforce it using Lithium Disilicate or Zirconium dioxide (eg:SUPRINITY-VITA).

Moreover, we should note that ceramics badly supports occlusal reductions. In fact, they are often at the origin of fracture due to the fatigue phenomenon. A meticulous polishing is therefore essential following such retouches.

***The luting systems**: it is admitted ,nowadays ,that esthetic inlays should be bonded. Bonding is a necessary condition for the longevity of indirect partial restorations . The bonding joint plays the role of constraints absorber to redistribute them to all the tooth.

Thanks to its thickness, it allows to have an idea about the inner adaptation of the restoration.

Based on the studies dealing with the choice of the bonding materials for IBPR,we can conclude that:

-Resin cements with etch and rinse adhesives remain the most used and lead to more reliable results.

-**Self -adhesive resins** have satisfactory results (Rely X Unicem as an example) that can be improved by a **prior enamel etch**ing .**Dual curing resins** seem to have better luting quality (Variolink is very documented in the studies we analyzed).

The size and location: It is admitted that the importance of the restoration extent represents a risk factor. In fact, the more the width and depth of the preparation increases, the more the residual dental structure resistance decreases.

Concerning the location, there seems to be no difference between the mandible and the maxilla. However ,the clinical prognosis seems to be more favorable for the premolars than the molars. In fact, they are more accessible and they undergo less occlusal constraints than the molars .It is worth noting ,however, that some studies do not show significant differences.

Pulp vitality: It is a real controversial issue. According to some studies ,esthetic inlays onlays present a better prognosis on the pulped tooth. However ,this result is not proved in the majority of in vivo studies .In fact, we have noticed that several studies showed that pulp vitality has no impact on the longevity of the restoration.

Occlusal overload/bruxism:

The presence of an occlusal para-function seems to greatly reduce the longevity of ceramic inlays onlays .We have to be prudent in case of patients with bruxism who need to wear bite splints at night.

Conclusion:

Data analysis of the retained articles in this systematic review has allowed to show the reliability of IBPR inlays onlays types .In fact ,it presents an important mean survival rate (higher than 90%).However, there are some failures . Happily, their causes are well-identified.

Knowledge of the indications, the material properties and the preparation and bonding rules represent the parameters to be mastered in order to guarantee the success of these restorations.

Table I: The different clinical studies related to composite resin inlays onlays

Authors / year (study scheme)	Used materials	Bonding materials	Duration of follow-up	Number of restorations /patients	Survival rate	Number of failures	results
Leirskar et col;2003 (clinical follow-up)	Light-curing microhybrid composite Tetric Z100 Maxxim	**dual-curing resin cements**	59 **months**	64/ 25patients	*95%*	*3*	2:fractures 1: Secondary caries 18(among successful IO) had imperfect anatomical form, mostly absence of proximal contacts *inlays/onlays made from Tetric, Z100, and Maxxim performed equally well over the 5-year period. The 3 types of composite showed satisfactory result.
kukrer et col;2004(A Prospective Clinical Study	**Micro-hybrid composite Ceromer**	**dual-curing resin cements**	**53 months**	**99**	**97.9%**	**2**	2 failures: fracture, Secondary caries 29% of the restorations were placed in patients with parafunctional habits such as bruxism or clenching.
Signore et col ; 2007(A Prospective Clinical Study)	**Micro hybrid composite :**	**dual-curing resin cements**	**6 years**	**43**	**93.02%**	**3**	*3 failures: needed endodontic treatment (3weeks, 2months, 5months) *5 IO with a significant increase in marginal discoloration * Bonded indirect resin composite onlays can be successful in treating painful, cracked teeth. From the findings of this study, it appears that cuspal protection should be incorporated into the design of coronal restorations.
Barone et col;2008(prospective clinical study)	**Micro hybrid composite : Signum composite**	**a light cured resin composit**	**3** years	**113/30 patients**	**97.4%**	**3**	3: fracture or loss of marginal integrity *Neither the size of the restorations nor the tooth type significantly affected the clinical outcome of the restorations.. *all IO present a loss of marginal integrity
Manhart et col;2008(a longitudinal randomized controlled clinical trial)	**Micro hybrid composite : *Composite Artglass *Charisma**	**dual-curing resin + Solid Bond Twin look 2bond2**	**3** years	**155/89 patients**	**89.8% Artglass 84.1% Charisma**	**5 10**	15failures: postoperative symptoms,bulk fracture and loss of marginal integrety *No significant differences were recorded comparing premolars and molars *,Small inlays showed significantly better outcome for some of the tested clinical parameters
Huth et col;2011(a longitudinal randomized controlled clinical trial)	**Micro hybrid composite *Composite Art glass *Charisma**	***dual-curing resin cements**	**4** years	**155/89**	**87.2% Artglass 76.6% Charisma**	**5 11**	16:5 Artglass and 11 Charisma inlays failed because of postoperative symptoms, bulk fracture, and loss of marginal integrity. * No significant differences between both composite resin materials could be detected *The comparison of restoration performance with time yielded a significant increase in marginal discoloration and postoperative symptoms, deterioration of

							surface texture quality, marginal and restoration integrity for both inlays *Small inlays compared to large inlays and premolar restorations compared to molar restorations showed significant better outcome for some of the tested clinical parameters for the Artglass inlays (p<0.05). For Charisma inlays, no such influences were revealed.
Barabanti et col; 2015 **(follow up clinical trial**	composite resin	***dual-cured resin composite cement Calibra** ***a light cured resin composite Filtek**	**10** years	**48/23**	**91% Calibra** **94% Filtek**	**2** **2**	*a comparable clinical performance of indirect composite resin inlays/onlays placed with a light cure or dual cure luting procedures.

Table II: The different clinical studies related to ceramic inlays onlays

Authors / year (study scheme)	Used materials	Bonding materials	Duration of follow-up	Number of restorations /patients	Survival rate	Number of failures	results
Sjögren et col;2004 (follow-up study)	Felds c: CEREC-CAD CAM	* dual-curing resin cements * a chemically cured resin composite	10 years	66/27	89% dual-curing resin 100% a chemically cured resin composite	7	4: fracture of the ceramics 1: fracture of the cusp 1: hypersensitivity (postoperative pain) 1: endodontic treatment * CAD/CAM-manufactured (Cerec) ceramic IO have shown satisfactory results. * The properties of the luting agents seem to affect the longevity of the type of ceramic inlays evaluated. (chemically cured resin composite have fewer failures)
Schulte et col;2005(follow-up study)	heat-pressed glass ceramic: IPS empress	*a light-curing composite resin.	116 months	810/390	96,7%	27	*5: fracture of the ceramics 1: fracture of the cusp 10:loss of adhesion 10: needed endodontic treatment Factors such as endodontic condition of the tooth, type of the tooth, position of the tooth, extent of the restoration, experience of the operator or gender of the patient had no significant influence on the survival probability of the ceramic restorations. * Heat-pressed glass ceramic inlays and onlays can be used successfully in routine clinical therapy. In addition, this type of inlays and onlays can be placed successfully with solely light-curing composite resin.
Krämer et col ; 2005(A prospective controlled clinical study	CRL IPS empress:	four different resin composite systems	8 years	96/34	92%	8	6: fracture of the ceramics 2: required endodontic treatment * 98% of the surviving restorations exhibited marginal deficiencies, independently of the luting composite Neither the absence of enamel margins, nor cuspal replacement significantly affected the quality of the restorations.

Krämer et col;2006(A prospective controlled clinical study	IPS empress:	two luting systems : *3MESPE (EBS Multi+Compolute) *IVOCLAR (Syntac+Variolink)	4 years	94/31	96%	4	4: hypersensitivities (3compolute et1 /Variolink) 55%: of cases had overhangs 38% showed marginal ditching * Between the adhesives ,No differences were found for the surface roughness, color matching, tooth integrity, proximal contact, hypersensitivity, and satisfaction
Krämer et col;2008(A prospective controlled clinical study	IPS empress	two luting systems : : *3MESPE (EBS Multi+Compolute) *IVOCLAR(Syntac+VariolinkIIlow)	8 years	94/31	90%	7	5: hypersensitivities (3compoule and 1 Variolink) 2: fracture * no difference between the two luting systems *Significant deteriorations were found for marginal integrity *Compolute was more prone to wear
Galiatsatos et col;2008(follow up clinical trial)	IPS empress: Ivoclar Vivadent	* dual-curing resin cements	6years	64/29	93.7%	3	*2:fracture;1: Secondary caries IPS Empress ceramic inlays and onlays are clinically acceptable. However, a disadvantage is the dissolution of the resin matrix of composite resins in oral fluids
Neaselius et col; 2008 (controlled clinical trial	--	*dual-cured resin cement*chemically cured resin composite cement	4years	130/91	93%	6 s	1: Secondary caries 5: molar fracture Ceramic onlay therapy is an acceptable treatment alternative over a 4-year period * No significant difference between the two types of two luting systems (dual and chemically cured resin cement)
Frankenberger et col; 2009 (controlled clinical trial)	IPS empress	4 luting systems : Tetric Variolink ultra Variolink low Dual cement	12 years	96/34	84%	15	*12: bulk fractures *Secondary caries was not observed. *significantly more bulk fractures were found when light-curing composite was used for luting *Restorations luted with dual-cured resin composites revealed significantly fewer bulk fractures.
Krämer et col;2009(A prospective controlled clinical study)	Cergogold (Degudent)	2luting systems : *IVOCLAR SV(Syntac+Variolink Ultra) *Definite multibond MD+Definite)	4years	57/24	95.2% IVOCLAR 93.3% Ormocer	4	3:ceramic fracture 1:dental fracture *a statistically significant deterioration was detected for both groups regarding the criteria of marginal adaptation, filling integrity (cracks/chippings/fractures), and tooth integrity *hypersensitivity is more likely to happen with a light-curing composite resin.
ATali et col;2011(clinical evaluation)	Leucite reinforced glass ceramic IPS empress	2luting systems : Self adhesive resin cement *etch and rinse multistep resin cement	3years	20/20,	100%	0	*no failure a statistically significant deterioration was found for the critiria marginal integrity,anatomical form and surface roughness *no difference between the two luting systems was detected
Murgueito et col;2012(clinical evaluation)	Leucite reinforced glass ceramic IPS empress	*IVOCLAR(etch and rinse multistep resin cement	3years	210/99	96.,67%	7	*7 failures : ceramic fracture (material thikness<2mm) *vital teeth are less likely to fail than non vital teeth *second molars were five times more susceptible to failure than first molars.
Tashner et col;2011(A Prospective Clinical Study)	IPS empress:	2luting systems: *3MESPE *IVOCLAR	2years	83/30	-	-	*better marginal and tooth integrity was found in the group of inlay onlay luted with etch and rinse resin cement compared to the use of self adhesive cement. *the dental location does not influence the treatment success *there is no significant difference between the two luting systems

Peumans et col;2013(randomized clinical trial)	Discilicate of lithium reiforced glass ceramic: IPS empressII	Self-adhesive dual curing resin cement with or without prior etching	4years	62/31	95%	3	2:loss of adhesion 1:fracture *prior enamel etching does not have an impact on the luting quality *an obvious deterioration in the marginal integrity was observed after 4 years in 95% of the cases
Nejatidanesh et col; 2015 (retrospective study)	Felds c: 2 blocs *CEREC bloc *Empress CAD bloc	Duolink bisco composite à prise duale	5years	159/109	96% CEREC bloc 94,6% Empress CAD	7	3: ceramic fracture 1:loss of adhesion 3:necessity of root treatment * the location (M or PM) and the size do not have an impact in the treatment success * More failures on depiluted teeth * No significant difference between the two types of blocks
Starsding *et al.*, 2020	Glass-ceramic (IPS)	dual-curing resin cements	11.2±4.3	54/36 A=107, B=25	80.4/80.0	22	Ceramic fractures (10.6%) and chipping (2.3%) were the most frequent complications. Six biologic complications occurred (4.5%).
M alament KA et al 2021	pressed lithium disilicate glass	dual-curing resin cements	10years	304 / 556	93.9%	6	bulk fracture or large chip

table III: Comparative clinical study between resin and ceramic inlays onlays

Thordrup M et col ; 2006 (A Prospective Clinical Study)	*direct Ceramic (Cerec Cos 2.0), *direct composite (Brilliant DI, *indirect Ceramc (Vita Dur N), *indirect Composite (Estilux, Kulzer)	--	10years	58/37	80%	12	9 : secondary caries / fractures 3 : persisting hypersensitivity or pulpal damage 80% of restorations were in function after 10 years including the 6 repaired ones(they were repaired for minor fractures) *during the observation period, the surface of vita dur N inlays became significantly rougher *the survival rates were within the range of survival for direct composite restorations

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