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Performance evaluation of the composite resins inlay/onlay: narrative review

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Resumo

O aparecimento de novos materiais restauradores levou a restaurações indiretas que estão a meio caminho entre as restaurações diretas em resinas compostas e as restaurações de prótese fixa. Estas restaurações indiretas são aplicadas em boca por colagem. Existem 3 subtipos: *inlays, onlays* e *overlays*, sendo diferenciados pelo seu grau de cobertura cuspídea.

Esta evolução foi possível graças não só ao aparecimento de novos materiais, mas também aos avanços técnicos no campo da adesão. O sucesso das restaurações indiretas depende dos materiais utilizados, do respeito pelas indicações, do procedimento de colagem e da metodologia de implementação.

O objectivo deste trabalho é definir o conceito de *Inlays/Onlays*, averiguar as indicações, contra-indicações, protocolo e eficácia destas restaurações em resina composta, de acordo com os dados científicos.

Para a realização deste trabalho, foi feita uma pesquisa de artigos científicos com as palavras-chave: "inlay", "onlay", "resina composta", "protocolo", "desempenho", nas bases de dados *on-line: PubMed, Sci-Hub and Scielo*.

Abstract

The emergence of new materials for dental restorations has led to indirect restorations which are halfway between direct restorations in composite resins and fixed prosthesis restorations. These indirect restorations are assembled by bonding. There are 3 subtypes: inlays, onlays and overlays that are differentiated by their degree of cuspidian coverage.

This evolution has been made possible not only by the arrival of new materials, but also by technical advances in the field of bonding. The success of indirect restorations depends on the materials used, the respect of the indications, the bonding procedure and the implementation methodology.

The aim of this work is to define the concept of Inlays/Onlays, clarify the context of indications, contraindications, protocol and performance over time this kind of restorations in composite resin, accordingly with scientific database.

In order to carry out this work, a search for scientific articles with the key words "inlay", "onlay", "composite resin", "protocol", "performance" will be done, in the online databases: PubMed, Sci-Hub and Scielo.

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Abbreviation

IO: Inlays/Onlays

CR: Composite Resin

DBA: Dentin Bonding Agent

DDS: Delayed dentin sealing

VDO: Vertical Dimension of Occlusion

IDS: Immediate Dentin Sealing

SUMMARY

I. INTRODUCTION

The rehabilitation of a tooth following carious or endodontic decay is a daily act for all dentists. In the recent decades, the evolution in restorative and prosthetic dentistry is pushing us to an ever more non-invasive approach in our treatments. (Bonafous D., 2018)

These non-invasive approaches my now include direct and indirect restorations. This evolution was made possible thanks to the arrival of new materials and also to technical advances in the field of bonding. (Toledano C., 2017).

The three etiologic cases of losing dental structures are carious lesion, traumatic lesion and wear lesions. The dentist's goal here will be to replace the dental loose always guided by the following parameters: restore the natural shape and function of the tooth, ensure its strength and durability and give it good aesthetics. (Dahan L, Raux F, 2010)

In conservative odontology, we can classically distinguish between two types of restorations: direct restorations, consisting of placing a biomaterial in the plastic phase in the residual cavity and allowing it to harden there, and indirect restorations, requiring a laboratory or machining for making the restoration. (Girault A., 2020)

The fundamental choice criterion between a composite direct posterior and a composite inlay/onlay is the residual biomechanical resistance of the tooth to be restored. (Charles, D. 2012)

The objective of this thesis is to define the concept of Inlays/Onlays (IO), clarify the indications, contraindications, protocol and performance over time of these kinds of restorations in composite resin. This information could provide elements to guide the dentist daily practice towards a reasoned choice of restoration according to the clinical situation and the desired results.

1. Material and methods

In order to do this work, a research bibliographic was made on the database PubMed, Sci-Hub and Scielo with the keywords "inlay", "onlay", "composite resin", "protocol", "indications", "performance", between the years of 1972 to 2022. After lecture and analyse of the scientific

articles and bibliographic reviews, only 46 were picked for their utility and their pertinence to this work. In addition, this work was compiled information sourced from the internet as well as several French journal and reviews.

Keywords: Inlay, Onlay, composite resin, protocol, indications, performance

II. DEVELOPMENT

1. Definitions

The difference between direct restoration and indirect restoration is related to the amount of the dental material remaining. When a tooth has too much damage for a direct restoration but not so much to necessitate a crown, we are able to use IO. (Dahan L and Raux F, 2010)

An “inlay” is a prosthetic part assembled by gluing or sealing. It is intended to restore a loss of tooth substance that does not require cusp coverage. An “onlay” has the same goal but it restores one or more cusps. These prosthetic elements can be metal or composite resin or ceramic material. (CNEOC, 2010)

The composite resins are special resins formed by units called monomers. These monomers are in free conformation in the space. Whenever we use UV light to polymerize these monomers, multiple chains are going to be created and bind them into polymers. However, this process is never total and some monomers are going to stay without binding or be partially bonded to a chain. During the change of conformation, the conversion rate corresponds to the proportion of monomer which reacted and bound. (Knobloch LA e*t al.*,1999) During their polymerization, composite resins shrink. Indeed, the conversion of monomers into a network of polymers leads to a replacement of Van der Waals bonds by shorter covalent bonds between the molecules. (Chaumont, PE, 2012).

When bonding a composite resin to the walls of the cavity, polymerization stresses develop at the bonding interface (composite/tooth bond). These forces are not distributed evenly along the walls of the cavity (Kinomoto Y. and Torii M., 1998).

Thus, at the level of the surfaces where the retraction forces are greater than the bonding forces, hiatuses are potentially created leading to carious revisions and post-operative sensitivities. (Pashley D.H., 1990).

2. Restorative approach

There are two different techniques used in dentistry, the direct and the indirect. (Girault A., 2020)

In **direct restorations**, after the cavity's preparation the resin composite is placed directly and is light cured. This is a quick procedure that preserves the maximum of the tooth structure. This corresponds to the concept of minimum invasive restoration and maximum conservation of the tooth. These direct restorations are doable in one appointment, quickly and inexpensively. However, they are associated with polymerization shrinkage and low wear resistance. (Angeletaki F. *et al.*, 2016), (Feilzer AJ, *et al.*, 1987).

When a composite is made using the direct technique, the conversion rate is around 50-60%. This means that about 40-50% of the remaining monomers are free or partially bound. (Knobloch LA. e*t al* 1999)

In **indirect restorations**, the restoration is made outside the oral cavity from an impression of the prepared tooth. This technique does not bear the disadvantage of the direct resin composite: the polymerization shrinkage. (Bausch JR, *et al.*, 1981) Furthermore, it provides better physical and mechanical properties, ideal occlusal morphology, proximal contouring and wear compatibility with opposing natural dentition. (Wassell RW, *et* al., 1995). However, this technique requires two appointments and is more costly for the patient. (Duquia Rde C, *et al.*, 2006)

In the indirect technique, the IO are done in the laboratory. This allows the prosthetist to use different methods to improve this conversion rate. (Barone A, *et al.*, 2008)

There are techniques to improve this rate and allow better cohesion:

- Heat treatment (10 to 30 minutes at 100-120°C). Using the incremental method, each layer is light cured as it goes. The conversion rate then reaches 70 to 80%. (Lovell LG, *et al.*,1999)
- A treatment with polymerization with a progressive or total reduction of oxygen (with for example a nitrogen atmosphere) (Ferracane JL and Condon JR,1992)
- A treatment with polymerization under moderate pressure (less than 10 bars) (Chaumont PE, 2012).
- A treatment with thermopolymerization for machinable composite blocks and discs with a conversion rate greater than 90 %. (Bausch JR *et al* 1981)

3. Indication/contraindication

According to the French National Authority for Health (HAS) in 2009, the indications and contraindications of IO are based on success factors and decision-making criteria to be taken into account during the clinical examination. (André C., 2016)

i. Success factors

The success of IO restorations will depend on many factors based on the patient, the dentist and the material. (André C., 2016).

Patient	**Dentist**	**Material**
Oral hygiene	Evaluation of the tooth's loss	Type of material
Motivation	Value of residual structures and pulp vitality	Properties physico-chemical
Cooperation	Respect indication/contra indications	bio compatibility
Tooth: occlusion, parafunction, harmful habit	Preparation of the cavity	
Age		
Aesthetic expectation		

Table 1. Different success factors of IO composite resin (Bodin. T. *et al.* 2009)

ii. Decision-making criteria

All these parameters must be taken into account:

- Hygiene
- Cariosusceptibility
- Patient motivation
- Allergy
- Patient's age
- Aesthetic requirement
- Financial possibilities
- Loss of tooth substance
- Situation of the cervical limits: supra or infra gingival, presence or absence of peripheral enamel
- Occlusion
- Parafunction (Bodin, T *et al*., 2009)

Depending on these criteria, a type of restoration is indicated or contraindicated. (André C. 2016)

Generally the dentist has three choices:

- In the case of a small loss of substance, direct restoration
- In the case of moderate loss of substance, direct restoration if this allows satisfactory restoration of the occlusal anatomy and the proximal contacts. Otherwise, IO by indirect method.
- In the case of significant loss of substance, indirect restorations by IO. (Bodin, T *et al*., 2009)

The fundamental choice criteria between a direct restoration and an IO is the residual biomechanical resistance of the tooth to be restored. The presence of marginal ridges is, in this sense, particularly important. Indeed, the loss of one marginal ridge leads to a decrease in tooth strength by approximately 50%. The loss of two marginal ridges leads to a decrease of the tooth strength by about 63%. (Charles, D., 2012) (see annex 1: loss of resistance)

The mainly indications of IO restorations with composite resin are:

- Significant loss of substance greater than 1/3 of the width Vestibular lingual (Inlay) or loss of a cusp (onlay)
- Site 1-2, stage 3-4 (SisTa classification) (see annex 2: SisTa classification)
- Multiple restorations on the same quadrant: to restore occlusal and proximal contacts
- Restoration of the occlusion plan in case of loss of VDO (Vertical Dimension of Occlusion)
- Pulped or depulped teeth
- Economic Considerations
- Justa/supra gingival cavities: to place the rubber dam in order to respect the bonding procedures
- Satisfactory periodontal state
- Good dental hygiene
- Motivated patient and low individual caries risk (Bodin, T *et al*., 2009)

Alternatively, this kind of restorations also has some contraindications :

- More than half of the tooth structure is missing
- Para function (bruxism)
- Marked cusp inclination
- Anterior teeth
- Many cases of fractures, cracks
- Lack of hygiene
- The limits are subgingival
- The Le Huche index is the ratio of the coronal mesial-distal diameter of a tooth in its widest part to its cervical mesial-distal diameter. A high Le Huche index indicates a significant flare of the tooth. The “Le Huche” index is unfavourable generating a risk of fracture linked to excessive bending stress at the proximal level. (Check annex 3 : index Huch)
- The bonding surface is limited. (Franiatte ME., 2005) (Bodin, T *et al*., 2009)

4. Cavity preparation

When sizing the cavity, the most important factor is the residual biomechanical strength of the tooth to be restored. Therefore, to make an indirect composite inlay/onlay:

- The walls must be at least 2 mm thick
- The thickness of the cavity must be everywhere greater than 1.5 mm in order to reduce the risk of IO fracture
- The bottom of the cavity must be flat and the preparation must not present sharp angles, which could fracture the prosthetic part;
- The walls will have a minimum taper of 10°.
- The opposing teeth must not have static occlusal contacts nor dynamic with the limits of our preparation
- The distance between the proximal cavity and the adjacent tooth must be a maximum of 2 mm, because too wide a mesial distal overjet can generate bending forces greater than the resistance of the composite, leading to a fracture of the IO.
- The cervical limit must be supra gingival (Zaghba A. *et al* no date)
  (Check annex 4: Decision tree IO)

5. Protocols IO

i. First clinical session

Shade's choice

The shade should be taken at the beginning of the session before the rubber dam is put in place, to avoid dehydration of the tooth and a change in the shade. (Franiatte ME., 2005).

The preparation

The preparations (size of the cavity) for composite IO must meet the precise criteria stated above. The practitioner will clean the entire cavity while preserving as much healthy tissue as possible, allowing the IO to be inserted and allowing its stability. (André C., 2016)

Pulpal protection

One of the characteristics of the indirect technique is the time required to complete it. During the time between the appointments, the protection of the dentin-pulpal tissues is done through what is called dentin hybridization. This step aims to ensure a seal of the dental tubuli to preserve the pulp and minimize post-operative sensitivities. (S.Koubi, G. *et al.,* 2008)

Delayed dentin sealing (DDS) is traditionally performed with indirect restorations. With this technique, dentin is sealed after the provisional phase at the cementation appointment. It was demonstrated that this chronology does not provide optimal conditions for bonding procedures.

Immediate dentin sealing (IDS) is a new approach in which dentin is sealed immediately following tooth preparation, before making the impression. (Magne P. *et al,* 2005). The IDS technique helps to achieve improved bond strength, fewer gap formations, decreased bacterial leakage and reduced dentin sensitivity. (Qanungo A. *et al,* 2016).

The technique described focuses on the use of the total-etch technique (also called “etch and rinse”), which can include either three-step (separated primer and resin) or two-step (self-priming resin) dentin adhesives. Etching of the freshly cut dentin with orthophosphoric acid (H3PO4) for 5–15 seconds must immediately follow tooth preparation to avoid saliva contamination. Following rinsing, excess water must be removed. (Magne P., 2005) The next steps can include the application of either the primer (three-step systems) or the self-priming resin (two-step systems). Following a first curing (regular mode 20 s); a layer of glycerine jelly is applied to the adhesive and slightly beyond. Additional curing (regular mode 10 s) of the Dentin Bonding Agent (DBA) through a layer of glycerine jelly is recommended. (Magne P. 2005)

Dental impression

The impression is made with a double-mixed silicone technique. It will be necessary to take an impression of the antagonist with irreversible hydrocolloids (alginate). To record the occlusion, a bite registration is made. (André C. 2016)

Temporisation

Temporary fillings can be made using a conventional self-casting technique with acrylic resin. They are then cemented with temporary cement, preferably without eugenol. (Dahan L, Raux F, 2010) It can also be made with an unglued polymerized composite. (Franiatte ME., 2005).

The use of eugenol-based temporary cement (MRI) can be problematic if there is an eugenol contamination of the cavity walls (which inhibits the setting of bonding resins). However, etching with 35% orthophosphoric acid will neutralize the eugenol. This type of temporization can therefore be used on condition that the preparation is cleaned carefully and etched completely afterwards. (Toledano, C. 2012)

ii. Second clinical session

After receiving the IO from the laboratory of the prosthetist.

Removal of the temporary restoration

After anaesthesia, the temporary restoration is removed and the cavity is cleaned with an ultrasonic device that removes cement residue.

Fitting and adjustment of the IO

The IO is first checked on its model and then directly in the mouth. A certain number of points must to be checked: the morphology, Marginal adaptation, proximal contacts and Aesthetics.

(S.Koubi, G. *et al.*, 2008)

Placement of the operating field

Before bonding an IO, a rubber dam is placed on the affected tooth. It prevents any salivary or haemorrhagic contamination of the cavity. (Zaghba, A. *et al* no date)

Bonding procedures

The intrados of the inlay is sandblasted with 50 micron aluminium oxide and etched with fluorhydric acid (10%). After rinsing and degreasing it is silanized for 1 minute before being dried. A layer of bonding resin is applied, and the inlay is set aside in a dark place. This bonding resin is not yet polymerized because it would create an extra layer making the bonding to thick and would be harmful to the insertion of the IO. (S.Koubi, G. *et* al., 2008)

The tooth cavity is treated in the usual way. The amelo-dentinal etching prepares the dental tissue for the hybrid layer. It is followed by a rinsing of at least the same duration as the application time. Depending on the products used, the amelo-dentinal adhesive should be applied in strict accordance with the manufacturer's instructions. As with the inlay surface, the bonding resin placed on the tooth is not cured. The dual bonding composite is injected into the cavity and the inlay is placed. (Dahan L, Raux F, 2010)

A first photopolymerization of 2 to 4 seconds will stabilize the IO and freeze the bonding composite. While keeping a pressure on the IO, the bonding excess are removed. Finally, we complete the bonding by a photoplymerization on each side of the tooth. It is now possible to remove the rubber dam, check the occlusion and polish with diamond drills and silicon tips. (Zaghba, A. *et al* no date)

6. Longevity and Risk of failures

Indirect composite restorations are an alternative to direct restorative techniques, (Decup *et al*., 2003) a study concludes with an almost identical survival rate, 97.5% for inlays versus 98.4% for direct composites (Cetin *et al*., 2013).

The survival rate of IO's is, however, satisfactory in the medium and long term: 93% at 6 years (Signore *et al*., 2007) and 83% at 11 years (Pallensen et al., 2003).

For composite resin inlays-onlays, Cetin *et al* (2013), report in their study with an average observation period of 5 years, survival rates of 97.5%. Survival of composite resin partial restoration posterior is satisfactory in the medium and long term with 93% at 6 years. (Cetin *et al* 2013).

One of the last studies on indirect resin composite IO done in 2022 showed acceptable long-term clinical results. The success rate of the restorations at 9-year follow-up was 85% and the failure rate was 15%. (Galiatsatos A. *et al.* 2022)

According to the studies presented above, the main cause of failure for composite IO is fracture of the material. It can be associated with postoperative sensitivity and an overall change in the restoration can be described (Weil *et al*., 2014).

III. DISCUSSION

Faced with large coronary cavities, the indication of direct restorations is often neglected because of their difficulty to perform and the unpredictable results, in favor of indirect restorations: inlays and onlays. (Dahan L, Raux F, 2010)

The difference between the two techniques did not reach statistical significance in order to recommend one technique over the other. The scarcity of primary studies supports the need for further well-designed long-term studies in order to reach firm conclusions about both techniques. (Angeletaki F. *et al*., 2016)

The first clinical session includes four major steps: preparation of the cavity, dentin hybridization, impression, and temporization. The greatest rigor during each of them determines the prosthetic result and the biological integration of our restoration. (Dahan L, Raux F, 2010)

The IDS should ideally be performed before the impression of the prosthetic piece. All materials used from cavity preparation to inlay-onlay assembly (imprint, temporary filling, temporary cement) will contaminate the dentin. The bonding to freshly milled dentin is therefore of better quality and allows better bonding values regardless of the adhesive system chosen. (Magne P. 2005)

The study performed by Scotti R. *et al*. (2002) concluded that temporary filling with soft temporary resins for a period of no more than one week provides a good temporary seal. Because of their intrinsic mechanical retention, inlays can be temporized with a soft resin. However, for onlays with less mechanical retention, it is preferable to seal the soft resin after polymerization with a temporary cement. (Toledano C, 2012).

The use of eugenol-based temporary cement (IRM) may be problematic in terms of eugenol contamination of the cavity walls (which inhibits the setting of bonding resins). However, (Tjanet AH. and Nemetz H. 1992) have shown that etching with 35% orthophosphoric acid neutralizes eugenol. This type of temporization can be used on condition that the preparation is cleaned carefully and etched completely afterwards.

The second clinical session also consists of four steps: treatment of the intrados, treatment of the tooth surface, assembly of the IO, and finishing. Bonding IOs is a complex procedure that requires a good knowledge of the principles of adhesion and perfect planning of the clinical steps. (Dahan L, Raux F, 2010)

According to the report of the French National Authority for Health (HAS) in 2009, adhesives without adhesion potential "are the only ones with the best clinical performance and the best results in terms of mechanical and aesthetic properties". They perfectly meet the specifications of an aesthetic, reliable and durable bonding.

A meta-analysis performed by Morimoto, indicates that the survival rate of inlays, onlays, and overlays remains high, irrespective of the follow-up time (5 y and 10 y) and regardless of the ceramic material, study design, and study setting. Their results indicate that fractures remain the most frequent type of failure. The type of tooth does not seem to affect survival rates, but restorations survived longer on vital teeth. (Morimoto S., *et al.* 2016).

The causes of failure are fracture of the restoration or tooth, the appearance of marginal defects or re-cavity, the presence of post-operative sensitivities, alteration of the shade, wear of the joint and therefore of the assembly material. (Dahan L, Raux F, 2010; Fron Chabouis H. *et al*., 2013).

A resin composite restoration may be considered defective as a result of secondary caries, chipping or fracture of the resin composite or the tooth or presence of marginal defects. In this case we can either intervene or control. The intervention would be repair of a defective resin composite restoration in a permanent molar or premolar tooth with resin composite. Whereas the control would be a replacement of a defective resin composite restoration in a permanent molar or premolar tooth with resin composite. (Sharif MO. *et al.*, 2014).

IV. CONCLUSION

Direct posterior composite is preferred in small cavities or if undercut results in excessive tissue loss. In other situations, the composite inlay/onlay is the winning strategy.

They allow for compensation of the loss of substance and to durably reinforce the dental tissues that have been weakened. However, no biomaterial or bonding method can restore the original strength of the tooth in its entirety, and any loss of tissue leads to a decrease in resistance to fracture.

Indeed, composite IO offers better control of polymerization and is therefore a greater guarantee of adaptation at the edges, as well as better control of the occlusal and proximal anatomy. This makes it possible to obtain an aesthetic restoration, reinforced by bonding and presenting improved clinical longevity.

IO's are contraindicated in cases where more than half of the coronal structure is missing, on the front teeth or in cases of severe parafunction. They can sometimes present postoperative sensitivities.

Nevertheless, composite IOs have innumerable advantages. First of all, adjustments and repairs are possible in the mouth without having to redo the restoration. They offer excellent peripheral marginal adaptation, good adaptation to occlusal conditions, almost no shrinkage during polymerisation, abrasion resistance avoiding premature wear and high mechanical qualities, as well as an almost ideal elastic modulus.

However, more studies are needed to evaluate the performance of indirect restorations with composite resin.

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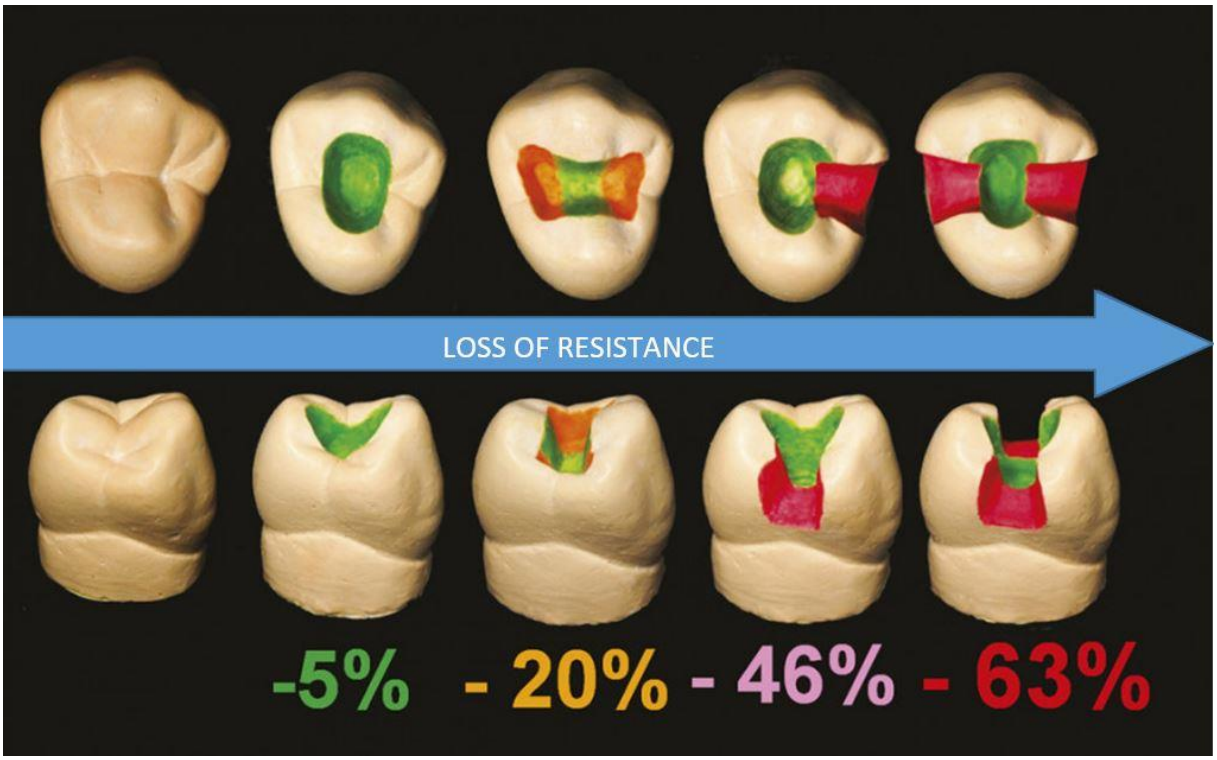
VI. ANNEXE:



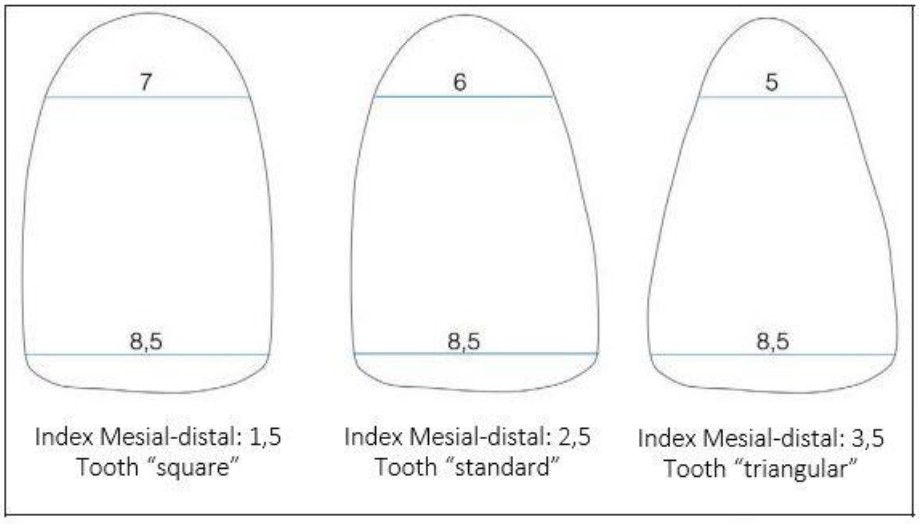
Annex 1 : Loss of Resistance

O. Corne, *et al*. (2015). Indications and preparations of bonded ceramic inlays-onlays concepts and guidelines. *Revue d'odonto-stomatologie.*

size site	0 No cavity	1 minimal	2 moderate	3 enlarged	4 extensive
1- pit & fissure.	1.0	1.1	1.2	1.3	1.4
2- contact area	2.0	2.1	2.2	2.3	2.4
3- cervical	3.0	3.1	3.2	3.3	3.4

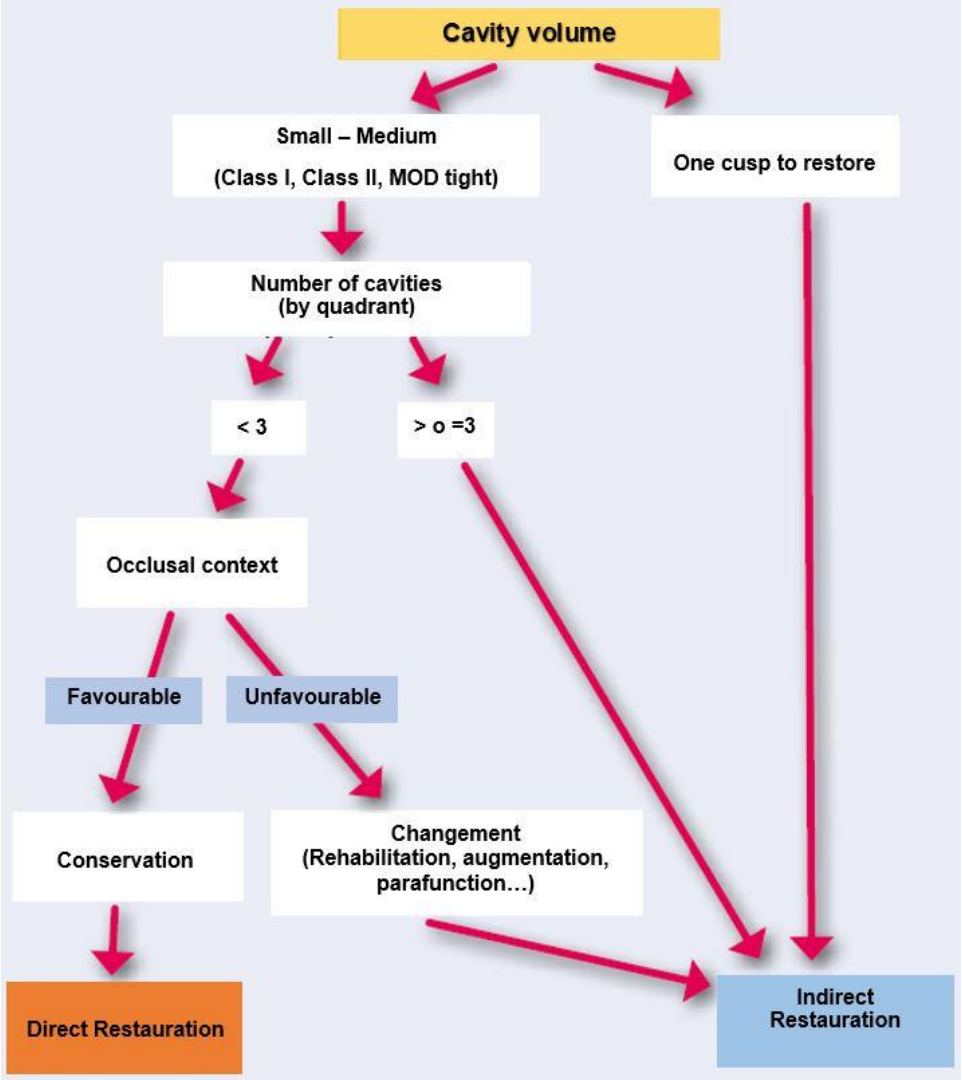
Annex 2 : SisTa Classification

Classification of Dental caries. (2013). Slidesshare. Consulted the 15th mai 2022, <https://pt.slideshare.net/rashaadelragab/classification-of-dental-caries-rasha-adel-copy>



Annex 3 : Le Huche Index

Le Huche R. (1951) Inlays et onlays/bridges sur dents vivantes.



Annex 4 : Decision Tree

Dahan L, Raux F, (2010) L'INFORMATION DENTAIRE n° 34.