Universidad Europea

GRADUATION PROJECT

Degree in Dentistry

COMPOSITE RESIN INJECTION TECHNIQUE FOR DIRECT VENEERS

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ABSTRACT

Introduction: Composite Resin (CR) intrinsic characteristics and techniques, are intimately connected between them, to the extent that they are able to affect each other both positively (e.g. layering of different CRs, allows the reproduction of natural tooth color), and negatively (e.g. restoration fracture which may derive from gap formation, due to CR hand manipulation). Thus, it is fundamental that to changes in materials, follow modifications in techniques, and viceversa. It is the case of Composite Resin Injection Technique (CRIT), recently developed in conjunction with new flowable CRs, to overcome, or at least reduce, previous limitations such as wear, fracture resistance, microleakage, discoloration and chairside time. **Objectives**: to present the protocol for CRIT when direct veneers are made, to review the clinical problems for which CRIT has been used to manufacture direct veneers, and to review the materials used to perform CRIT when fabricating direct veneers. **Material and Methods**: once inclusion criteria were set, 7 databases, and 11 search equations, some of which were including Boolean operators, were used to carry resource searches. **Results**: A total of 514 articles were found. Articles which were repeating throughout the searches, and throughout the same search, were in total 16, and were therefore excluded. 470 papers were excluded due to not following the inclusion criteria and were not in line with the topic. The total number of articles used for this final review project were 28. **Conclusions**: CRIT is characterized by a relatively simple, fast, cost-effective, and truly conservative protocol, which can be successfully applied to the manufacturing of direct composite veneers, through the use of specific flowable CRs; however, larger clinical studies and longer follow-ups are needed, in order to better understand potential longevity of CRIT-manufactured direct composite veneers.

Keywords: Dentistry; Composite Resin Injection Technique; Direct Veneers; Dental Aesthetics; Restorative Dentistry.

RESUMEN

Introducción: Las características intrínsecas y técnicas de la resina compuesta (RC) están íntimamente conectadas entre sí, en la medida en que pueden afectarse entre sí tanto positivamente (por ejemplo, la estratificación de diferentes RC, permite la reproducción del color natural del diente), como negativamente (por ejemplo, la fractura de la restauración que puede derivar de la formación de espacios, debido a la manipulación manual de la RC). Así, es fundamental que a los cambios en los materiales, sigan las modificaciones en las técnicas, y viceversa. Es el caso de la Técnica de Inyección de Resina Compuesta (TIRC), desarrollada recientemente en conjunto con las nuevas RC fluidas, para reducir las limitaciones previas como el desgaste, la resistencia a la fractura, la microfiltración, la decoloración y el tiempo en el consultorio. **Objetivos**: presentar el protocolo para TIRC, revisar los problemas clínicos por los cuales se ha utilizado, y revisar los materiales utilizados, todos con respecto a la fabricación de carillas directas de composite. **Material y Método**: una vez establecidos los criterios de inclusión, se utilizaron 7 bases de datos y 11 ecuaciones de búsqueda por recursos. **Resultados**: Se encontraron un total de 514 artículos. Los artículos que se repetían, eran en total 16, y se excluyeron. Se excluyeron 470 trabajos por no seguir los criterios de inclusión y no estar alineados con el tema. El número total de artículos utilizados para este proyecto de revisión final fue de 28. **Conclusiones**: TIRC se caracteriza por ser un protocolo relativamente simple, rápido, rentable y verdaderamente conservador, aplicable con éxito a la fabricación de carillas directas de composite, a través del uso de RC fluidas específicas; sin embargo, se necesitan estudios clínicos más amplios y seguimientos más prolongados para comprender mejor la longevidad potencial de las carillas de composite directas fabricadas con TIRC.

Palabras clave: Odontología; Técnica de Inyección de Resina Compuesta; Carillas Directas; Estética Dental; Odontología Restauradora.

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I.INTRODUCTION

Since 1940, after having replaced acrylic resins, which on their turn were replacing silicate cements as main materials, composite resins (CRs) revolutionized and dominated restorative dentistry field scenario (1-3), even though, the word “composite” was still not used in the early ‘60s for the purpose of indicating the resin used in modern practice, but rather to indicate a mixture of equal or different material phases (4). Such huge protagonism of CRs, was thanks to discoveries like that of Buonocore in 1955, that demonstrated the key role of orthophosphoric acid in improving CRs enamel adhesion (1, 2), and that of Bowen in 1962 who, beyond developing a new molecule named bisphenol A glycidylmethacrylate (bis-GMA), was able to coat silica with a coupling agent named silane, and combine it with bis-GMA, creating the basic formula, characterized by improved mechanical properties with respect to that of past materials, which is still used in daily restorative dentistry, and which has signed the 1st “composite revolution”, lasted from 1963 to 2012 (2, 4).

CRs were somehow substituting previous materials due to their superior characteristics. In fact, they were showing reduced postoperative sensitivity and discoloration, improved resistance to microleakage with consequent less risk of secondary decay occurrence, and were allowing major preservation of healthy tooth structure. However, microleakage due to polymerization shrinkage, postoperative sensitivity, discoloration and abrasion are still weak points of such materials, even with the last composites developed (1, 3).

To reduce such weaknesses of CRs, and increase longevity of composite restorations, research and development of new monomers-based composites, as well as of new additional components, curing systems, and strategies of treating CRs with the objective of improving their behavior (e.g. heating of CRs), spread since their introduction, and actually got to that which is known as the 2nd “composite revolution” (1-5). Such development of materials, consequently pushed that of techniques as well (5-11).

The master techniques for direct composite restorations, which represent milestones in CRs manipulation, and that are still used on daily clinical practice, are the incremental layering and the stratified layering techniques (5, 11). While the former is the most used for any kind of direct composite restorations, the latter is preferred in the case of performing aesthetic restorations. However, with the aim of adapting the resin to the cavity created, and of creating layers of resin with the correct thickness to allow a proper curing, both techniques are based on hand manipulation, which causes generation of gaps which, in the long term, can lead to fracture of the restoration, thus to functional failure (5). As well, when it comes to the anterior area, CRs discoloration can lead to aesthetic failure (5). Moreover, when it comes to highly aesthetic anterior cases management, due to the fact that the procedure to make direct composite restorations is usually time-consuming, and that high skills are often needed, indirect restorations such as veneers are preferred and commissioned to a dental technician, thing that steps up particularly the price for patient's dental treatment (6).

CR's intrinsic characteristics and techniques are intimately connected between them, to the extent that they are able to affect each other both positively and negatively.

Thus, with the purpose of overcoming limitations of previous techniques and materials, such as wear, fracture resistance, microleakage, discoloration and chairside time, it is assumed that we are facing not only a 2nd "composite revolution", but also a 2nd "technique revolution". In fact, other methods are being developed, such as the composite resin injection technique (CRIT), which has been recently described (9, 10), and that represents an evolution of the already known "index technique" (7, 8), with which shares several common aspects, but also substantial differences (6-8). Though, what is important to mention, is that aim of both techniques is obtaining monolithic direct composite restorations, which take the advantages of both indirect monolithic restorations, and of direct resin composite restorations, or strength, high esthetics, longevity, healthy tooth structure preservation, reduced cost and reduced chairside time (5, 7, 8, 9, 10).

The main aim of this literature review is to present the protocol for CRIT when direct veneers are made by presenting the latest advances in CRs and their techniques, and providing deeper insights on features of CRIT, in particular its performance`s protocol, as well as documented applications in literature and materials used to fabricate direct veneers.

II.THEORETICAL FRAMEWORK

1. CRs: brief history, latest developments, and future perspectives.

In 1963, Dr. Ray Bowen was able to successfully coat silica particles with silane, and to mix them with bis-GMA and other components, generating CR's "original" formula which would have dominated the next 50 years (1, 2, 4). In Table 1, it is possible to appreciate as, since its formulation, such mixture hasn't changed much until about 2010.

Generic components in Bowen's* original and modern (circa 2010) resin-based composites.

COMPOSITE COMPONENTS	COMPOSITION OF REINFORCED RESIN-BASED COMPOSITE	
	1963 Original (Bowen*)	2010 Typical
Coupling Agent	Vinyl silane	Vinyl silane
Matrix: Acrylic Comonomers	80 percent bisphenol A-glycidyl methacrylate (bis-GMA), 10 percent methyl methacrylate, 10 percent triethylene glycol dimethacrylate (TEGDMA)	70 percent bis-GMA, 30 percent TEGDMA
Inhibitor	Hydroquinone	Butylated hydroxytoluene
Filler	55 volume percent quartz, < 150 micrometers	55 volume percent glass, < 0.5 µm
Initiator	Benzoyl peroxide	Camphoroquinone and others
Accelerator	N,N-Dimethyl-amino-p-toluidene	Visible light
External Interfacial Bonding	None	Etching-priming-bonding system

* Source: Original 1963 JADA article by Bowen.

Table 1. CRs "original" Bowen's formula vs. "modern" formula (4).

This has been due to very limited availability of coupling agents (chemicals able to link different phases interface), and their unique characteristics (pH dependence, necessity of thin film formation, and better behavior when diluted), but also due to the fact that CR design can be very tortuous, given all the different chemicals that need to coexist (2, 4). This, led to the fact that the first "composite revolution", which we can appreciate in Figure 1, has been characterized mostly by modifications of size and amount of inorganic filler, and polymerization methods, while the main matrix, made of bis-GMA, has not been changed (1, 3, 4).

About polymerization methods, the first mechanism implied chemical activation (or self-curing). However, such procedure entailed serious problems, such as air entrapment, and poor working time control (2). For this reason, this method has been substituted by light polymerization, specifically by ultraviolet first, and subsequently by blue visible light activation (2), which is still the most used method nowadays. Light activation, overcame previous limitations related to self-curing procedure, while presented with the limitation based on which a specific relation must exist between thickness of CR layer placed, and light intensity and

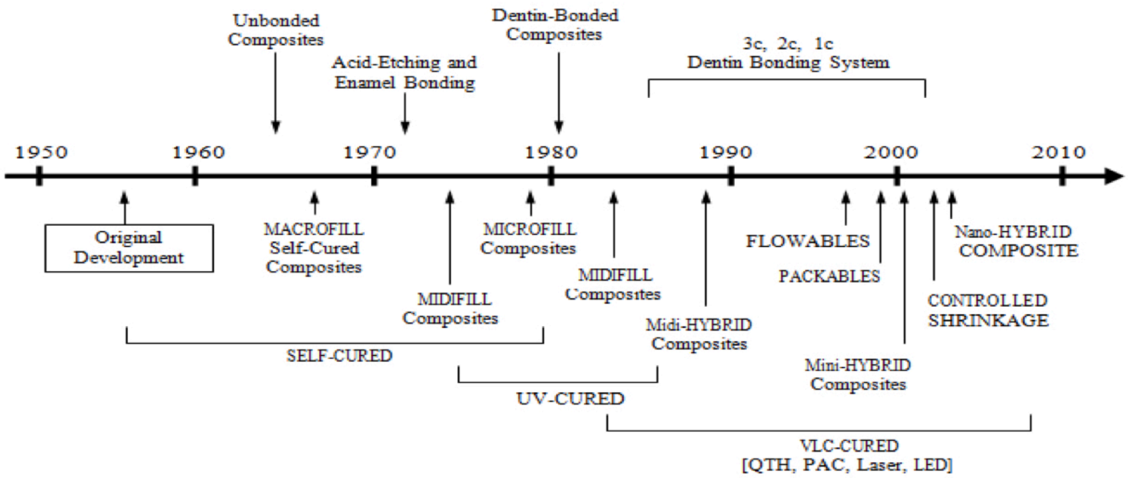

Figure 1. Development of CRs during the 1st "composite revolution" (1).

exposure time applied to it (specifically, 2-3 mm CR layers have to be polymerized with 425-491 nm light intensity, and for a time frame of 40 seconds) (1, 2). Conversely, more recently developed technologies, such as plasma arc and argon laser, led to an exposure time of respectively 10 and 5 seconds. If on one hand, due to higher intensity and shorter exposure time, these last have been proved to reduce chairside time, on the other hand it has been demonstrated that they cause excessive stress accumulation, with consequent higher risk of sooner restoration failure (2).

About inorganic filler size and amount modifications, from microfills, which were showing very good polishability, but scarce mechanical resistance, and that were mainly used for small aesthetic Class III and V restorations, we passed in a first instance to midfills and hybrids, which were showing better mechanical resistance, but high wear sensitivity, and that were mainly used to restore mid to large posterior cavities; however, the above mentioned CR types had considerable wear and aesthetic problems, which led to micro- and nanohybrid CRs (also known as universal), which were showing superior polishability and longer gleam detention with respect to previous, and were used for any kind of restoration (1, 3). In Table 2, it is showed the Lutz and Philips classification of CRs, based on filler size and amount (1).

However, just playing with size and amount of inorganic filler particles, only improved resistance to fracture and wear, while other characteristics, as for example the elastic modulus, did not significantly improve (3, 4).

In fact, the so called 2nd "composite revolution", focused instead on reducing polymerization shrinkage (or the phenomenon by which, stress arises at the interface tooth-restoration as a consequence of the dealing of CR with rigidness of prepared cavity walls), which is the responsible for potential restoration detachment, fracture generation due to gaps, postoperative sensitivity, and secondary decay occurrence (2, 3).

Composite resin type	Particle size	Particle percentage
Megafill	50-100 µm	-
Macrofill	10-100 µm	70-80%
Midifill	1-10 µm	70-80%
Minifill	0-1-1 µm	75-85%
Microfill	0.01-0.1 µm	35-60%
Hybrid	0.04-1 µm	75-80%
Nanofill	0.005-0.01 µm	-

Table 2. Lutz & Philips classification of CRs based on filler size and amount (1).

To achieve so, a 1st strategy implied the development of new monomers characterized by higher molecular weight with respect to bis-GMA (e.g. high molecular weight urethane, high molecular weight phase-separating dimer dicarbamate dimethacrylate). Thanks to their reduced content of reactive functional groups (3), and their particular chemistry (2), such higher molecular weight monomers were promising in reducing polymerization shrinkage. However, even though *in vitro* results showed effective reduction in shrinkage, clinical results did not, and this looks to be attributed to the interference of biological factors, such as patient's diet and hygiene, bacterial biofilm, and peculiar occlusion charge (3).

Another strategy, concerned the introduction of new monomer-based technologies (e.g. "silorane" ring opening tetrafunctional epoxy siloxane polymerization). Such technology, takes the advantage of working through an opening and "expanding" monomer, after polymerization, to reduce shrinkage. Even though showing the highest elastic modulus and the lowest shrinkage, also this monomer looks to be affected by biological factors mentioned above (3).

More recent strategies, known as thiolene methacrylate, covalent adaptable network, and the addition of "stress modulators", involved stress reduction, and thus shrinkage reduction, through mechanisms such as polymerization time delay, and bonds recycling (capability of covalent bonds, to disrupt and reform in response to stress) (3). Even though, products and available information on these last are limited, first data show effective reduction in gap generation (3).

Finally, we can say that remarkable steps forward have been done in CRs modification, with the aim of improving their intrinsic characteristics, and their behavior at the moment of their manipulation. And the final result, or lengthening longevity of composite restorations, has been more than surprising, if juxtaposed with expectations at the time of their launch (3). Nevertheless, it's not the end. Interestingly, close future trend in CRs, looks to be more directed towards an improvement of the capability of such materials in relating not only with the tooth itself, but with entire mouth system, in the way of mitigating the negative effects of biological factors mentioned above (3). An example, is represented by antibacterial CRs. These materials are provided with chlorhexidine, or ions (fluoride, hydroxyl and calcium), which are released once the restoration is set, or with a specific monomer which prevents bacterial biofilm formation on the restoration (1).

1.1 Flowable composites.

Worth to mention for the purpose of this review, is the development of flowable composites, which were introduced in 1955 (1). They descend from hybrid composites, following a modification implying increased size and reduced amount of inorganic filler particles, or increased amount of triethylene glycoldimethacrylate (TEGDMA) diluent, which made them less viscous, and thus more “flowable” (1, 2). Even though characterized by low translucency, and by increased wear susceptibility and polymerization shrinkage, fluidity of these CRs made them particularly useful as cavity base, in Class V restorations, and in all that occasions characterized by difficult access (1, 2). A first attempt of modification, led to flowable bulk fill CRs, which were even less viscous materials capable of being placed in multiple and thicker layers, without the need for intermediate polymerization steps (1). More recently, flowable composites have been the target of further modifications, having as aim that of making them easier to manipulate, more translucent, and less subject to polymerization shrinkage (2). Finally, the advent of new techniques such as CRIT, has recently expanded the spectrum of use of such type of CRs, as we will see later on.

1.2 The incremental and stratified layering techniques.

Composite placement method, it’s known to be one of the factors affecting CR shrinkage (11). When introduced, both incremental and stratified layering techiniques were promising reduced shrinkage, due to little amount of material placed at a time, reduced contact between opposite walls at the moment of polymerization, and reduced C factor (11).

The incremental layering technique, consists in the application of CR layers of maximum 2 millimiters, in a horizontal, oblique or vertical direction (Figure 2 A, B, C respectively), followed by their light polymerization one by one (11).

However, it has been observed, that the horizontal method was actually increasing C factor and stress deriving from polymerization, while the other two ways were effectively reducing them, with consequent reduction of secondary decays and post-operative sensitivity (11).

On the other hand, the stratified layering technique, was developed with an aesthetic aim, or that of reproducing the several shades normally found in natural

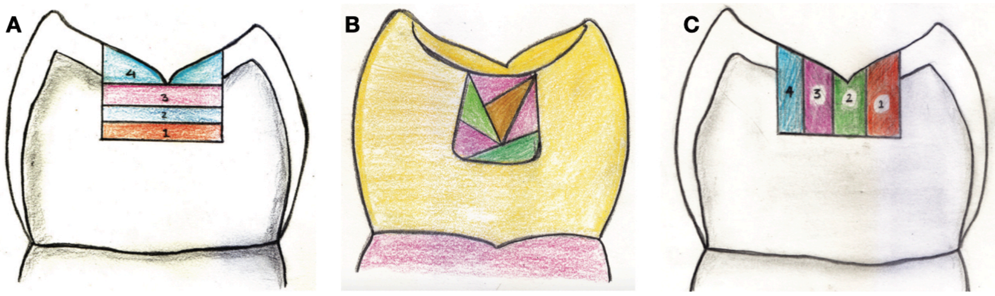

Figure 2. The incremental layering technique. A, horizontal layering; B, oblique layering; C, vertical layering (11).

tooth. To do so, layers of CRs with dentin shades are first placed in order to reproduce dentin color, followed by placement of opalescent CRs able to mimic enamel (11).

Even though, in most of the cases, both these techniques are still the referral point in restorative dentistry nowadays, they can lead to precocious functional and aesthetic failure, fact that pushed restorative dentistry to search for new techniques able to provide more long-lasting and aesthetic composite restorations.

2. The "index technique".

In the last decades, biological, functional and especially aesthetic concerns related to tooth ruin and loss, have become increasingly demanding. Moreover, the high costs and artificialty of implant and prosthetic rehabilitation, together with an increasing conservative "ideal", indirectly pushed restorative dentistry to find more economic and conservative solutions in order to meet the new requests.

For this purpose, a new approach, known as "index technique", has been proposed (7).

Briefly, such method works through obtaining an index from a previous wax-up of patient's teeth, the pre-treatment of teeth interested by the procedure with orthophosphoric acid and adhesive, the perforation of the index with the only aim of allowing excess composite to come out from it, the application of pre-heated flowable CR directly on the tooth, and then the placement of the index to shape that composite, which will be further polymerized, finished and polished (7). The specific protocol steps for it, are the following:

1. Clinical analysis of patient’s initial situation
2. Impression taking, and its casting
3. Wax-up creation on previously obtained cast
4. Generation of the index by placement of silicone material over the diagnostic wax-up, and its curing (3 minutes)
5. Index removal from cast, trimming, and cut for isolating single elements (by means obtaining a single index for each tooth that needs to be restored), and little perforation of each index to allow composite excess leakage during the procedure
6. Composite color determination (before performing tooth isolation, and avoiding direct chair light onto teeth)
7. Rubber dam isolation of teeth interested by the procedure, by taking care of placing also a stainless steel matrix between tooth interested by the procedure and adjacent, and by bending such matrix towards adjacent tooth
8. Try-in of indexes, and eventual their modification in order to achieve best fit at the level of each waxed tooth
9. Placement of pre-heated composite on teeth to restore through the use of a spatula, followed by placement of indexes, and curing of the composite (1 minute through the index, and 2 minutes after its removal)
10. Finishing, by using interproximal metal strips, discs and fine diamond burs
11. Polishing (7).

Specifically concerning veneering, Ammannato et al., showed the case of a patient seeking for modification of shape and size of both lower and upper anterior teeth, but without recurring to invasive procedures (7). In Figure 3, it can be observed the initial situation of patient’s mouth (7).

Figure 3. Patient's initial situation, before "index technique" realization for anterior upper veneering, and lower crown lengthening (7).

In Figure 4, it is showed how the index is fabricated from the wax-up, for subsequent veneering of upper anterior sextant (7).

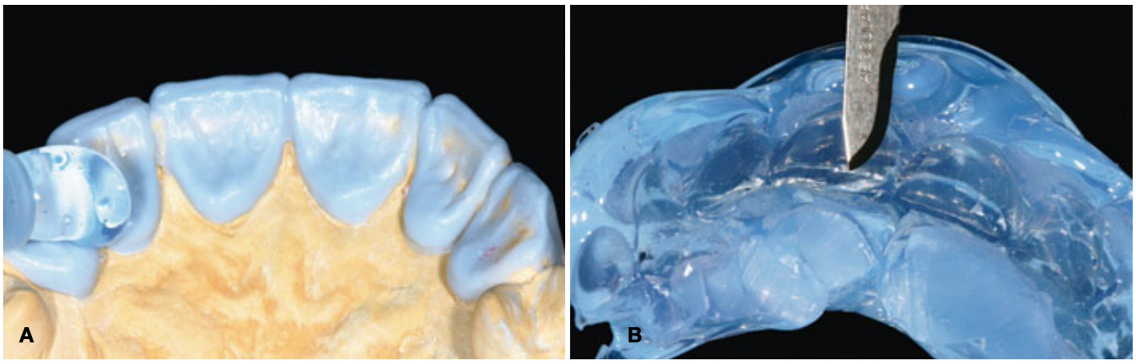

Figure 4. Index fabrication for veneering process. A, silicone placement over wax-up; B, index obtaining (7).

In Figure 5, it can be observed how, after etching and adhesion performance, pre-heated composite is placed onto the interested tooth, then the cut index is applied on each tooth separately to shape the previously placed heated composite, the polymerization process through the index, and the result after polymerization, but before finishing and polishing (7).

In Figure 6, it can be observed the immediate final result for composite veneering of upper anterior sextant, crown lengthening of lower anterior sextant, and the upper anterior sextant at 2 years follow-up (7).

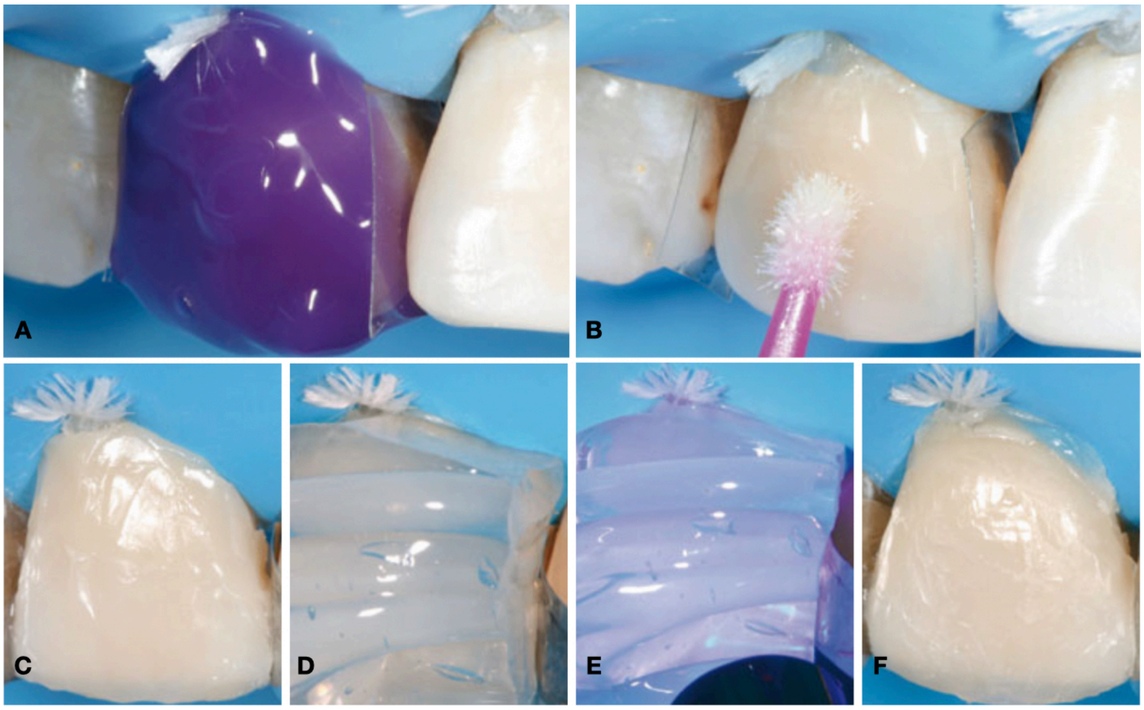

Figure 5. “Index Technique” for upper anterior sextant veneering procedure. A, orthophosphoric acid etching; B, adhesive application; C, pre-heated composite placement; D, customized index placement for composite shaping; E, polymerization through the index (1 minute); F, result after out of the index polymerization (2 minutes) (7).

Figure 6. Immediate and 2 years follow up result. A, upper anterior sextant veneering; B, lower anterior sextant crown lengthening; C, upper anterior sextant at 2 years from intervention (7).

In the same article, Ammannato et al., show how, besides veneering and crown lengthening, the “index technique” can be useful also to restore teeth in case of abrasion, or in the case that an increase in the Occlusal Vertical Dimension (OVD) is needed (7).
Such technique has been also digitalized more recently (8). Though, differences with the conventional, only lie in impression taking (realized through an intraoral scanner), casting (digital casts are obtained from digital impressions,), and wax-up, which is created through the software on digital models, and which can subsequently be printed by milling to be used as a model on which creating the index conventionally (8).

3. The CRIT.

CRIT, is a more recent technique (6), which since its introduction has been already applied to solve successfully a wide bunch of clinical dental problems, in both adults (6, 9) and children (10). In a more generalized and simplified way, such technique foresees the obtaining of an index from a previous wax-up of patient’s teeth, and the subsequent perforation of such index with the scope of inserting highly filled flowable composite tube tip through it, to then pushing the composite into the index which will fill the vacant spaces, and which will be finally polymerized by applying light through the transparent index (6, 9, 10).
Several articles (6, 9, 10), reported patient’s cases out of which the specific unified protocol steps for the technique can be summarized as following:

1. Clinical analysis of patient’s initial situation (Figure 7 A, B and C)
2. Impression taking with alginate, or better condensation silicone, and its casting with type IV plaster (this step may be also carried out through an intraoral scanner, through which the digital impressions may be converted into digital casts)
3. Wax-up realization on previously obtained cast (Figure 7 D, E and F) (this step may be also conducted digitally)
4. Silicone (usually polysiloxane) index preparation for mock-up realization (Figure 7 G), and subsequent try-in in patient’s mouth (as the previous

two, also this step may be conducted digitally, and in this case, the mock-up may be printed to further translate it into patient's mouth, or it could be also translated directly digitally on to initial photos of the patient)

5. Hydration of waxed-up cast in cold water for 5 minutes
6. Supply of transparent silicone (usually polysiloxane) all over the wax-up, trying to regularize it as much as possible, and in the way of obtaining a layer of roughly 2 mm thickness (Figure 7 H)
7. OPTIONAL: Transfer of the waxed-up cast with silicone to a depressurizing machine for 5 minutes, to avoid air entrapment in the silicone index
8. OPTIONAL: Transfer of the entire complex (waxed-up cast with silicone index) to a vacuum laminator, to cover the index and also adjacent teeth eventually not interested by the procedure, with a roughly 1 mm thick acetate sheet; this, will help the placement of the index in the exact spot, provide support, and avoid misshapement of it following CR injection (Figure 7 I)
9. Little perforation of the silicone index at the level of each tooth interested by the procedure through a diamond bur, and try-in of the silicone index in patient's mouth, followed by its removal
10. Tooth isolation with rubber dam, retraction chord placement, cleaning of tooth surface with free fluoride paste or others, like chlorhexidine 2% (to note: teeth interested by the procedure, are not treated all at once; each tooth to be treated in a first instance, has to be separated from the two adjacent by covering these last two with teflon, which will be treated with the same technique, but in a second moment) (Figure 7 L)
11. Etching of enamel tooth surface with 35-37.5% phosphoric acid for 15-30 seconds, followed by washing and drying of etched surfaces (Figure 7 M)
12. Application of the adhesive for 10-20 seconds, followed by its thinning through air spraying, and polymerization (Figure 7 N)
13. Placement of the index in patient's mouth, and insertion of tube tip of fowable CR in the previously created holes, and subsequent pushing of

the CR through the index, which will fill the vacant spaces between index and tooth surface (Figure 7 O)

14. Polymerization of CR through the index, from both vestibular and palatal/lingual, both for 30-40 seconds (Figure 7 P)
15. Pre-polishing of first teeth treated
16. Repetition of the technique until all teeth have been treated
17. Finishing and polishing of all treated teeth, through the use of discs, strips, rubber burs and paste (Figure 7 Q) (6, 9, 10).

Important to mention, is that if any step from 2 to 4, are carried out in a digital way, the workflow is to be considered partially digital. If instead, every step is conducted without any technology, the process will be completely conventional.

More recently, the “Bioclear Method” has been proposed as an alternative way of performing CRIT (5). Basically, differences between such more recent method and “traditional CRIT”, rely on slight modifications which are represented by:

1. cleaning of the tooth surface with aluminum trihydroxide (which will drive excess of CR to uncut enamel specifically)
2. use of specific prefabricated matrices from Bioclear, in the place of the transparent silicone index (beyond providing high level anatomy, these matrices are able to fit better interproximal and gingival spaces, allowing CR to flow also in the most difficult spots to reach) (Figure 8 A and B)
3. use of CR with different viscosities, and heated to improve flowability and adjustment capability
4. polishing made through a Bioclear patented kit (Figure 8 C and D) (5).

Figure 7. CRIT phases. A, B and C, initial patient's situation; D, E and F, wax-up on cast models; G, silicone index on wax-up for subsequent mock-up realization; H, transparent silicone index needed for CRIT performance; I, silicone index with acetate support; L, M and N, tooth isolation, acid etching and bonding; O, flowable composite injection; P, polymerization process through the index; Q final immediate result (6).

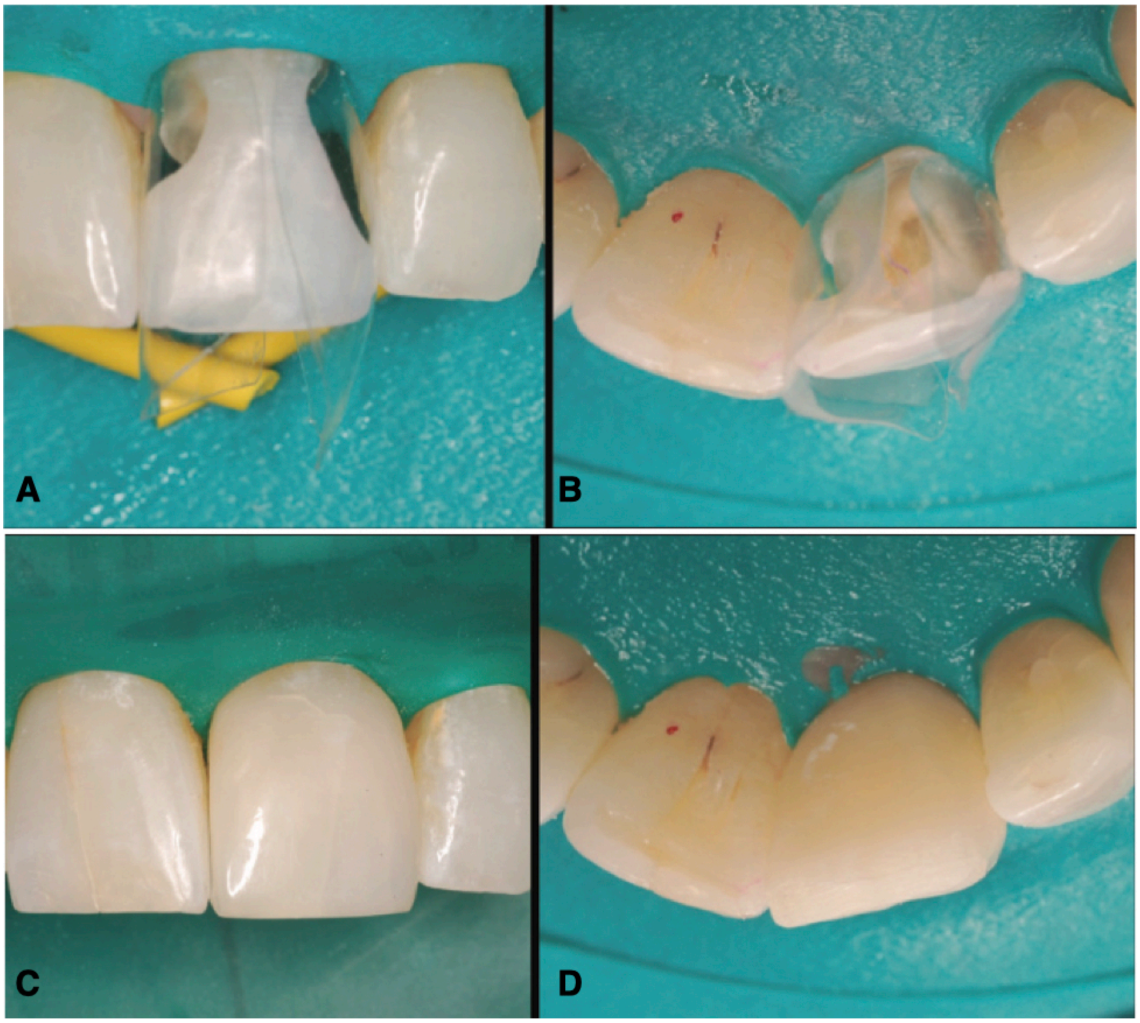

Figure 8. The “Bioclear Method”. A and B, prefabricated transparent matrices from Bioclear; C and D, final result after polishing with Bioclear patented kit (5).

III.OBJECTIVES

1.MAIN OBJECTIVE

The main aim of the present literature review is to present the protocol for CRIT when direct veneers are made.

2.SECONDARY OBJECTIVES

To review the clinical problems, documented so far in literature, for which CRIT has been used to manufacture direct veneers.

To study the materials, used to perform CRIT, when fabricating direct veneers.

IV.MATERIAL AND METHODS

This final research project is a review of the literature. Searches for resources on the topic, were carried out through the library of the Universidad Europea (Dulce chacon), by using the following databases: “Dentistry & Oral Science Source”, “Medline complete”, “Academic Search Ultimate”, “CINAHL with full text”, “E-Journals”, and “eBook Collection (EBSCOhost)”. Additionally, “Pubmed" database was also used. Search equations were the following: “composite resin injection technique AND direct veneers”, “composite resin injection technique AND veneers”, “composite resin injection technique”, “composite resin injection technique veneers” (for pubmed search), “history of composite resin”, “latest developments composite resin”, “injection molded composite dentistry”, “injectable resin composite restorative technique”, “index technique worn dentition”, “using injectable resin composite”, “composite incremental layering technique” (for pubmed search). Last date of consultation of databases for all these searches was 22nd November 2022. Inclusion criteria used for this review are shown in table 3. Conversely, exclusion criteria include types of research other than reviews, case reports, research articles and interviews, publications prior to 2012 and subsequent to last date of consultation of databases, gender other than male and female, and publications in languages other than English.

Criteria	
Type of research	Review Articles, Clinical Case Reports, Research Articles, Interviews
Published year	2012 to 2022
Gender	Male, Female
Language	English

Table 3. Inclusion criteria.

V.FLOWCHART

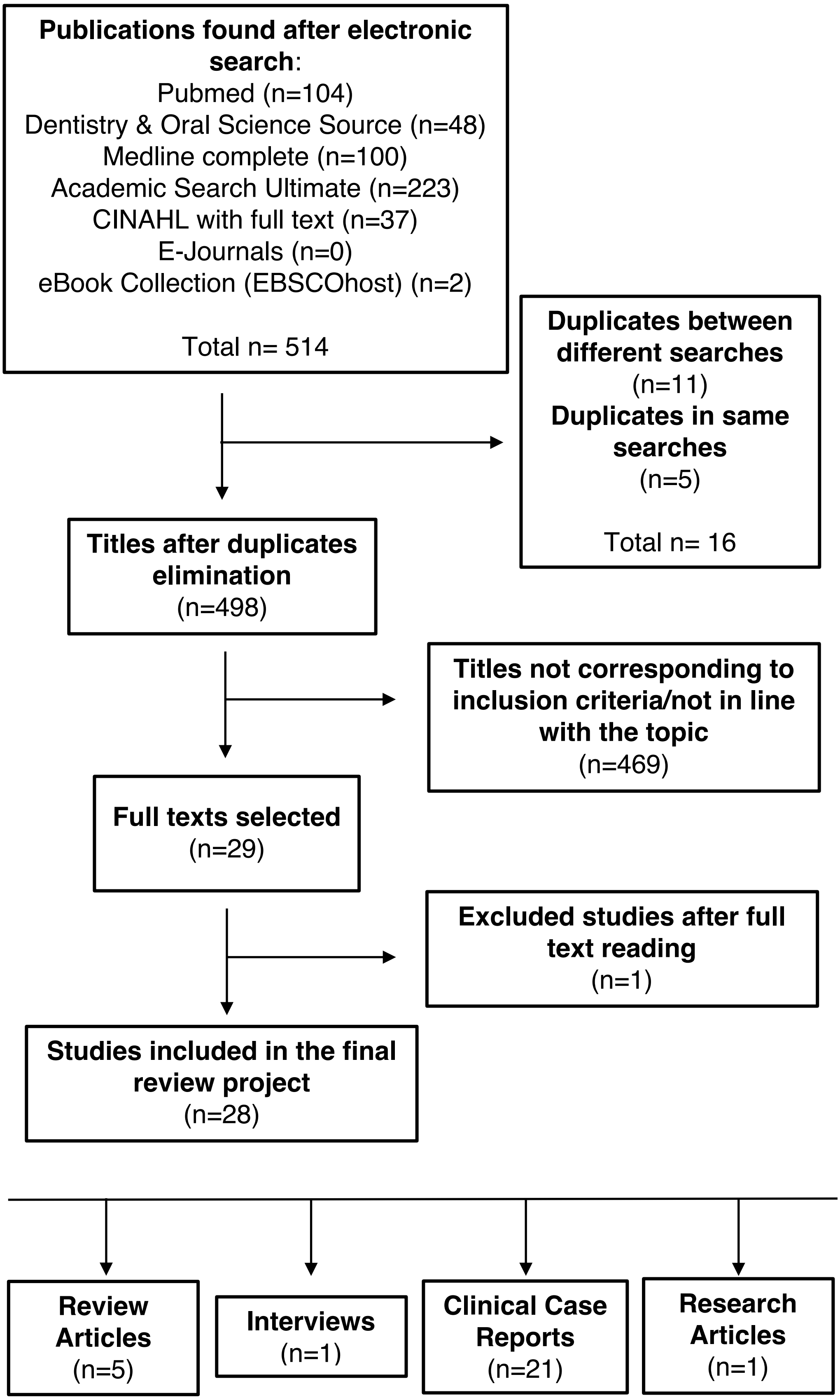

Figure 9. Resources selection process Flowchart.

VI.RESULTS

A total of 514 articles were found. Articles which were repeating throughout the searches, and throughout the same search, were in total 16, and were therefore excluded. Articles which were excluded, because not respecting inclusion criteria and not in line with the topic, were 470. Thus, the total number of articles taken for this final review project are 28. Table 4, shows most common clinical problems, and their resolution.

Table 4. Most common clinical problems, and their resolution through CRIT-based veneering.

Reference	Clinical problem	Methods used	Results	Follow-up
Geštakovski D, 2019 (12)	Aesthetic and functional concerns due to diastemas, insufficient tooth visibility, wear and occlusal problems	**Conventional CRIT**, **modified** (separation of mock-up into single tooth pieces)	4 vestibular composite veneers for teeth from 12 to 22, and 2 **360° composite veneers** for teeth 13 and 23 were successfully made	6 months frequency recalls, for a total period of 2 years (during such, no gingival inflammation, nor wear, were noticed)
Terry DA, Powers JM, Blatz MB, 2018 (13)	Aesthetic concern due to diastema between 21 and 22, and due to shorter length of 22	Post-surgery **conventional CRIT** to fabricate a direct “provisional” restoration on	As final result, a composite veneer for tooth 22 was successfully realized directly;	1 year after CRIT (the provisional restoration was still highly aesthetical, and

	with respect to 12 (recessions at 21, 22 and 23 level also)	tooth 22, then cut-back and transformed into final	diastema was closed, and tooth 22 lengthen	didn't show any sign of ruine)
Salem MN and Hafez S, 2021 (14)	Oversensitivity to temperature stimuli, and aesthetic concerns, due to erosive dental wear at 11, 21 and 22, and incisal edge fracture of 11	**Conventional CRIT**	3 composite veneers, for teeth 11, 21 and 22, were successfully directly realized	8 weeks (some gingival inflammation left, but good state of restorations, happiness of patient with outcome and total oversensitivity resolution)
Geštakovski D, 2021 (15)	Aesthetic concern about microdontic tooth 22, causing diastemas with adjacent 21 and 23, and about asymmetric smile, due to right posterior crossbite	Home bleaching, followed by **partially digital CRIT** (after being obtained conventionally, casts were digitalized and the digital wax-up used to translate exact shape of 12 to 22)	Composite veneers were successfully realized for tooth 22 and 14 (for this last, with the aim of adding material to make patient's smile symmetrical)	At 3 days for routine control, and at 10 months (no gingival inflammation, nor wear, nor composite change in color were seen)

Cortés-Breton Brinkmann J, *et al*. 2020 (16)	Chief complaint about aesthetics of smile, due to severe tetracycline staining and teeth malpositions	**Conventional CRIT** (in this case, minimally invasive tooth preparation of 1.5 and 0.2 mm in lower and upper arch respectively, was necessary)	16 vestibular composite veneers were successfully directly made (from 14 to 24, and from 34 to 44)	After 15 days, at 1 month, and then every 3 months up to 2 years, (the patient was satisfied with both aesthetics and function, and no wear, nor periodontal affectation were seen)
Chockattu SJ, *et al*. 2018 (17)	Severe and generalized erosion of palatal surface of upper teeth, due to gastro-esophageal reflux disease (controlled since 4 months at the time of exploration)	**Conventional CRIT**	14 palatal composite veneers were directly made, in order to cover all dentin exposures at the level of the upper arch	13 months (apart from slight color change in the gingival third, restorations were retentive and well adapted, and no wear was observed)
Coachman C, *et al*. 2020 (18)	Aesthetic concern about maxillary teeth, due to	Bleaching and gingivectomy, coupled with **partially digital**	10 vestibular composite veneers (for teeth from 15 to	No follow-up is mentioned

	diastemas, missalignment, and unequal tooth color and gingival line	**CRIT** (worth mentioning is that in this study, digital cast and digital wax-up have been overhanged to provide a guide for gingivectomy)	25) were successfully realized directly, to meet patient's aesthetic demands	
Terry DA, Powers JM, Blatz MB, 2019 (19)	Chief complaint of poor aesthetics due to fracture of tooth 21	**Conventional CRIT**, followed by cut-back, and layering of tints and translucent nanohybrid CR, to reproduce patient's natural teeth characteristics	A composite veneer for tooth 21 was directly realized, and patient's fracture was successfully corrected	No follow-up is mentioned
Maroulakos G, *et al.* 2021 (20)	Aesthetic chief complaint about space, due to loss of tooth 21 following trauma	Orthodontic treatment, followed by a digital smile design study and **conventional CRIT** (*no tooth	Direct composite veneers were made for tooth 11, and for teeth 22 and 23 in order to respectively	3 months (restorations were highly aesthetical, and no wear, nor discoloration, were observed)

		preparation was necessary)	"convert" them in a 21 and 22	
Hosaka K, *et al.* 2020 (21)	Chief complaint of poor aesthetics and function due to anterior crowding at the level of both arches, and right side posterior crossbite	Extraction of 11 and 21, followed by 3 years orthodontic treatment (12 and 22 were moved respectively at place of 11 and 21), and finally **partially digital CRIT**	4 veneers were directly fabricated to "convert" the lateral in central incisors, and the canines in lateral incisors)	5 months (restorations were highly aesthetical, and no wear, nor periodontal impairment were observed)
Ljubicic M and Zivkovic M, 2021 (22)	Aesthetic concern about smile appearance, due to multiple diastemas and tooth misalignment	13 months orthodontic treatment for general tooth alignment, followed by **partially digital CRIT**	4 **partial veneers** were directly made (specifically for disto-incisal of lateral incisors and mesio-incisal of canines), and diastemas closed	No follow-up is mentioned
Hosaka K, *et al.* 2021 (23)	Chief complaint of poor aesthetics and	**Partially digital CRIT**	In such study, CRIT was used first to build	3 months (no wear, nor periodontal

	function due to absent 31 and 41	Peculiarity of this study is the digital preparation (cut-back) performed; 2 transparent indices were fabricated	"prepared" (0.5 chamfer) 31 and 41, and then to veneer an enamel composite on top of the "preparations"	affectation observed)
Diaz E, *et al*. 2018 (24)	Chief complaint of poor aesthetics, due to fractured restorations at mesial of 11 and 21; additionally, the patient showed generalized dentition wear	Digital smile design study, followed by **conventional CRIT**	The upper antertior teeth, and the posterior worn teeth, were successfully directly veneered	No follow-up is mentioned, but the article highlights the need of clinical studies for better evaluation of durability of CRIT-obtained restorations
Clark DJ, 2020 (25)	Chief complaint of poor aesthetics, due to presence of black triangles between upper anterior teeth, and presence of dark stripes	Bleaching, followed by "**Bioclear Method**"	The technique was used to successfully produce 4 direct veneers; to note from this study, is that the adhesive used is not	No follow-up is mentioned

	on tooth 11 and 21		polymerized after its application	
Clark D, 2014 (26)	Chief complaint of poor aesthetics, due to post-orthodontic treatment generation of black triangles between upper and lower anterior teeth	"**Bioclear Method**"	Veneering of all upper and lower anterior teeth, with consequent "closure" of the black triangles	6 months (good overall status of the restorations)
Clark D, 2014 (27)	Chief complaint of poor aesthetics due to conoid 12 and 22, and consequent presence of large diastemas at the level of the whole anterior upper sextant	"**Bioclear Method**"	The complete upper anterior sextant was successfully veneered, through the use of anterior and diastema specific Bioclear matrices	No follow-up is mentioned

VII.DISCUSSION

The Composite Resin Injection Technique (CRIT), is a novel technique recently developed (6, 9, 10), in conjunction with the development of new flowable CRs (22, 28), with the aim of improving some of the current limitations clinicians still face in daily restorative dentistry.

First of all, it is important to point out, standing also with the results presented in this review, that with the development of such technique, restorative dentistry effectively stepped up towards the achievement of its aim.

1. CRIT's protocol for direct veneers:

The principle based on which CRIT and the "Bioclear method" work for the fabrication of direct composite veneers doesn't change, and it's represented by CR injection (5-6, 9-10, 26-27). However, there are specific differences in the execution protocols, worth to discuss deeply.

A 1st difference, it's represented by the pre-procedure tooth cleaning. For this step, while for "traditional CRIT", Ypei Gia, N.R. *et al.* (6), and Terry, D. and Powers, J. (9) suggest the use of a free fluoride paste, or of a mix of pumicing and irrigation with 2% chlorhexidine solution respectively, the "Bioclear method" take the advantage of using an aluminum trihydroxide air-water system (5, 26, 27); such system, beyond exploiting excess CR driving to uncut enamel specifically (5), provides, as stated by Clark, D., a superior plaque removal, if compared to the methods described for the "traditional CRIT", particularly in the interproximal area, preventing in this way potential future restoration staining and/or detachment (26, 27).

The 2nd, and potentially more important difference, lies in the fact that, differently from "traditional CRIT", in which the professional needs to fabricate a transparent index from previous impression taking, casting and wax-up performing (6, 9, 10), the “Bioclear method” uses specific patented matrices working as index, with the difference they are prefabricated (5, 26, 27); as stated by Clark, D., such matrices, thanks to their design, allow reduction in chairside time, given a wax-up is not really required; moreover, they rule restoration emergence profile already from subgingival, in its turn conditioning papilla position, thus providing superior results in terms of soft tissue respect and position once the restoration is complete (26, 27).

The 3rd important difference between “traditional CRIT” and “Bioclear method”, resides in the fact that while in the “traditional CRIT”, a single non-heated flowable CR is injected (6, 9, 10), the “Bioclear method” exploits the injection of a pre-heated mix of different viscosities CRs (5, 26). Benefits of CR heating are well known, and are summarized by Jihyon, K. (5), and Clark, D. (26).

The 4th difference, is about the polishing; in fact, differently from “traditional CRIT”, using standard polishing protocol based on polishing burs and pastes, the “Bioclear method” take the advantage from the use of a specific patented polishing kit from the company, working through 3 steps, and able to provide superior smoothness and brillance to the restoration (5, 27).

Since what has been discussed so far, data seem to support the superiority of the protocol of “Bioclear method” over that of “traditional CRIT”. Nevertheless, standing with the results presented in this literature review, both ways of performing it, have been proven to be applied successfully to manufacture direct composite veneers (12-27), with a significant tendency more towards the use of “traditional CRIT” protocol over that of “Bioclear method”. This could be due to several reasons. First of all, even though the “Bioclear method” protocol could lead to reduced chairside time, the necessity of sticking to the possession of all these patented elements from the company could result in a major expense for the professional. Then, if we look up the “traditional CRIT” protocol, we realize that a fascinating characteristic of composite injection, is that such technique is extremely versatile, allowing the clinician to introduce slight modifications to the general protocol, based on personal expertise, ability, comfort and available tools (12), a very important factor this in nowadays scenario, in which a growing tendency towards undervaluing clinician abilities and opinion is observed (5); this, could be not the same for the "Bioclear method" protocol, since the necessity to conform to its steps, due to the need of using the specific patented elements from the company.

2. Clinical problems solved through CRIT-manufactured direct veneers:

As described by Terry *et al.*, since its introduction, CRIT immediately revolutionized not only restorative dentistry, but also fields like prosthodontics and orthodontics, and spread fast, finding application, combining or even replacing most of the methods previously used, and ranging from resolution of simple problems, like for example single tooth fracture repair, to correction of OVD, tooth misalignment and full mouth rehabilitation (13).

The results presented in this literature review, confirm the previous assertion. In fact, with regard to the manufacturing of direct veneers, the range of clinical problems to which CRIT has been successfully applied so far it's wide, and goes from diastema/spacing (due to causes including also tooth missing and black triangles) (12-13, 15, 18, 20, 22-23, 25-27), color (18) and shape/dimension anomalies (13, 15, 27), dental fracture (14, 19, 24), aesthetic concerns due to dental malposition (15-16, 18, 21-22), dental stainings (16, 25), wear and consequent oversensitivity to thermal stimuli (12, 14, 17, 24), and occlusal problems (12). Such spectrum of clinical problems has a great potential for widening, as much as CRIT is applied boldly, and in daily clinical practice.

3. Materials used to perform CRIT:

Materials for CRIT performance, are easily extrapolatable from previous section in which the protocol for the technique is presented. Most of the studies presented in this review, report for CRIT performance, the use of G-aenial Universal Flo,

and G-aenial Universal Injectable, both manufactured by GC Corporation. The former has been tested in a study in which it has been compared with other recently developed flowable CRs, and was found to have superior abrasion resistance (22). The latter instead, has been the object of a very recent study, in which beyond being compared with other newly developed flowable CRs, it has been compared also with ceramic, and specifically for the fabrication of occlusal veneers; interestingly, following specific stress tests, this resin showed to be the less prone to wear and reported the lowest value for surface roughness (even less than ceramic), beyond showing also a high value for microhardness (inferior to that of ceramic, but similar or significantly higher if compared to other resins) (28).
These results, shed light on the importance for the clinician to be updated, and of choosing the best documented flowable CR, when it comes to CRIT performance, to provide the patient with stronger and longer lasting composite restorations.

It should not be forgotten that, with recent advances in flowable CR materials, and with CRIT development, restorative dentistry had as main objective that of obtaining monolithic direct composite restorations, which take the advantages of both indirect monolithic restorations, and of direct resin composite restorations, such as strength, high aesthetics, longevity, healthy tooth structure preservation, reduced cost and reduced chairside time (5, 7-10). This is particularly important, given the current state of the world, with its frequently fluctuating economic conditions (5), but characterized by high aesthetics demand and non-stop mindset. This, lays the foundations for futher discussion.

Specifically concerning manufacturing of direct veneers, and comparing for example CRIT with indirect manufacturing of ceramic/composite veneers, we can affirm that CRIT has proven to be 1) relatively easier to perform (even though, as it usually happens when it comes to implementation of new methods, an adequate learning curve it’s always necessary), 2) more cost-effective, 3) more conservative (since in most of the results presented in this review, we have seen that not even a minimal tooth preparation was necessary), 4) reduce overall chairside time (even though, worth to mention is also that through such technique we must treat one tooth at a time, and that thus an adequate planning of the time to perform it on a patient, based on the extent of treatment, is necessary).

About strength and longevity of direct composite restorations, several factors must be considered. If on one side, strength of direct bonding (as in case of composite), has been proven to be superior to that of indirect restorations (such as ceramic) (23), on the other side, the higher abrasion grade of composite respect to ceramic in the case of antagonism with natural tooth must be also taken into account (7). As it can be evidenced from the several studies presented in this review, CRIT allows direct bonding, obviating (or at least trying to reduce) risk for composite abrasion by the use of an occlusal splint, aiming to guard restoration from occlusal contact threads and to ensure durability (12, 16, 23). However, worth to mention is also that, given the novelty of CRIT, and restrictedly to direct veneers, the longer follow-up available and reported by results presented in this review is of 2 years (12, 16), and even shorter for the “Bioclear Method” (6 months) (26), thing that highlights the necessity for longer follow-ups, and larger clinical studies (24), in order to effectively have stronger data on potential longevity of direct veneers obtained through CR injection.

About aesthetics, even though superiority of ceramic over composite it is widely accepted, results presented in this review, not only show great patient’s aesthetic satisfaction (14, 16), but more importantly highlight the ability of CRIT of successfully managing difficult cases, as can be that characterized by severe tetracycline staining (16).

Additionally, beyond allowing the possibility of being performed also through a partially digital workflow (15, 18, 21-23), such technique can be easily combined with orthodontics (20-22), surgery (13, 18, 21), aesthetics (15, 18, 19, 21, 25), strengthening the multidisciplinary role of restorative dentistry.

VIII.CONCLUSIONS

It can be concluded that:

- when comparing CRIT with indirect manufacturing of ceramic/composite veneers, CRIT has been proven to be easier to perform, more cost-effective, more conservative and reduce overall chairside time.

- Bond strength of direct composite restorations have been proven to be superior to that of indirect.

- Composite resins have higher abrasion grade than ceramics in case of antagonism with natural teeth.

- Ceramics are aesthetically superior to composites, but great patient's aesthetic satisfaction has been demonstrated when using CRIT, especially in difficult cases such as severe tetracycline stain.

- Direct composite veneers can be successfully manufactured in the dental clinic, because CRIT allows direct bonding.

- To provide stronger and long lasting composite restorations, newly developed flowable CRs are needed.

- Larger clinical studies and longer follow-ups are in need to obtain sufficient and more trustful data on potential longevity of CRIT-obtained direct composite veneers.

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