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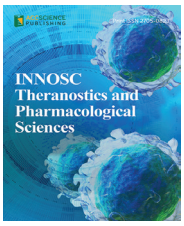

REVIEW ARTICLE

Adhesive Cementation of Ceramic Restorations: A Comprehensive Review

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Abstract:

The success and tendency of the indirect restorations were mainly affected by the patient and dental surgeon factors. The patient factors consist of their dietary, functional habits, and oral hygiene, while the surgeon factors consist of their management in tooth preparation, impression, and cementation. Among these factors, cementation is a very crucial step to ensure retention, durability, and marginal seal of indirect restoration. The field of dentistry has largely benefited from the various newer types of ceramic introduced. However, this cementation process can be either adhesive or non-adhesive. Adhesive cementation refers to the use of an agent that promotes the bonding of restorative material to substrate, whereas the non-adhesive cementation involves the use of luting agent for filling the gap between restoration and natural tooth. However, the indication for use of adhesive or non-adhesive cementation depends on various factors, such as resistance form, ceramic composition, available preparation retention, and field control during the cementation process. Hence, it is important for the clinicians and dental surgeons to understand these factors before selecting an appropriate cementation process for ceramic restorations. In this review, we provide an overview of adhesive cementation process for ceramic restorations and make appropriate recommendations for routine dental practice.

Keywords: Adhesive dentistry, Ceramic restorations, Cementation, Dental cements

1. Introduction

Dental restorations aim to restore lost tooth structure caused by factors such as decay or esthetic corrections. Indirect restorations, among various types of restorations, offer a more sustainable form and function, particularly when large decay is present. The success of these restorations depends on two factors: patient-related factors such as their dietary, functional habits, and oral hygiene, and clinician-related factors such as tooth preparation, impression, and cementation [1].

Contemporary ceramics have become popular among patients and clinicians for indirect restorations due to their optical properties, physical strength, and conservative preparation requirements [2,3]. However, the success of ceramic restorations depends on several factors, including fracture resistance, marginal fit, marginal accuracy, choice of cement, and cement thickness [4]. The choice of cement, in particular, plays a significant role in the retention and marginal seal of indirect ceramic restorations as they do not have secondary retentive features [4,5].

The cementation process can be either adhesive or non-adhesive [4,5]. Adhesive systems have significantly improved the longevity of indirect restorations due to their added benefit of chemical and micromechanical bonding [6]. Correctly,

applied adhesive cements have higher bond strength and low solubility compared to non-adhesive cements [7,8]. However, sustaining scrupulous isolation becomes crucial for the success of restoration in the case of adhesive cements.

It is important for dental surgeons to understand these factors to decide on the appropriate cementation process for ceramic restorations. This review will focus on the adhesive cementation process for ceramic restorations, its interaction with different ceramic compositions, and appropriate recommendations for routine dental practice.

2. Cementation procedure

The choice of cement depends on various factors such as resistance form, ceramic composition, cavity preparation, and isolation technique used during the cementation process [9,10]. Adhesive cement forms a hybrid layer between the ceramic and tooth interface. It binds micromechanically and chemically with ceramic and the tooth structure [6].

At the tooth interface, etching followed by priming and bonding is done. Resin cement binds with etched enamel and dentin, forming a hybrid layer resulting in resin tags. It was found that bond strength of ceramic-cement-tooth complex was higher than that of the individual bond strength of cement and tooth or cement and ceramic interface [7]. Short and tapered preparations benefit from the cementation process using the adhesive techniques. This is due to the hybrid layer formed that helps in improving the mechanical retention of restoration [8].

Based on their ability to etch, these cements can be total etch/etch and wash type where etchant is applied and rinsed off, or self-etch that does not require washing as the cement is incorporated with monomer and adhesive. However, self-etch cements were found to have a weaker bond strength to the enamel than that of the total etching system [2,9]. Hence, total etching 3-step adhesive system has been considered the gold standard process. The bonded layer should be prevented from contamination as it jeopardizes the cement adhesion to tooth structure. This requires good isolation which sometimes becomes a challenge in a normal dental setup [1]. In addition, the clinicians and dental surgeons must ensure that the technicians use certain precise methods for achieving proper adaptation, as the adhesive cement use might not compensate for its poor fit.

3. Surface treatment for the etchable ceramic restorations

Pretreatment of the ceramic interface improves adhesion of cement and the restoration. This is achieved by techniques such as air abrasion, sand blasting with aluminum oxide particles, or application of etchant. Studies have proven that among all the techniques, acid etching has yielded maximum bond strength and ceramic composition has played not much significant role in it [8]. Etching results in formation of microporosities that increase the surface area of the interface, enhancing wettability of the cement. This aids in micromechanical interlocking of cement at the ceramic interface and thus is a crucial step in the process of cementation. Different etch patterns are formed in successful adhesion process depending on the adequate cleaning of internal surfaces of the ceramic restorations. The resultant hexafluorosilicate formed after etching is rinsed off with water spray [11]. This etched surface is then salinized. The bifunctional molecule of silanes chemically bonds with inorganic part of ceramic and copolymerizes with the cement resin through organofunctional radical [12-15]. Efficacious action of the silane depends mainly on the hydrolysis by a weaker acid. The single-bottle system of the silane was pre-hydrolyzed and was found to have a shorter shelf-life with reduced effectiveness over a period of time. Hence, the double-bottle forms are mostly preferred [16].

4. Composition of ceramic and its bond strength at cement interface

The durability and strength of the bond at cement and ceramic interface depends on the mode of treatment selected. This in turn is governed by microstructure of the ceramic composition. Conventional ceramic has silica and potash feldspar and/or soda feldspar as their basic components. They are also rich in glass phase and have been found to have higher strength of bonding to resin cement [11-13].

When the surface treatments commonly used for the feldspathic ceramics are applied to the

ceramics with a higher content of alumina (Al_2O_3), the results were found to be poor [17]. Scarcity of glass phase has promoted neither the crystal exposure at ceramic structure nor the chemical reaction with silane, resulting in weaker bond with resin cement [17]. Hence, composition of particular ceramics system must be considered before surface treatment is chosen. However, this does not significantly affect the bond strength as compared to etching [8]. Depending on glass phase content of ceramic, it might be sensitive to the acid-etching or might be resistant to the acid [18]. Sandblasting procedure is an effective alternative procedure for conditioning of the aluminum oxide ceramic with little or no glass content. Given the greater amount of resistance to fracture of these ceramics, they could be cemented to the dentin using zinc phosphate or glass-ionomer cement [18]. Silicoating procedure is another effective alternative, which promotes durable bond with higher content of zirconium ceramics or alumina [17,18].

5. Types of ceramics and its interaction with adhesive system

While the clinicians and dental surgeons select the cementation procedure for the process of ceramic restorations, it is essential for them to know the structure, composition, and resistance form of the ceramics selected for fabricating the restoration process.

Based on their reaction to acid, ceramics are classified as acid-sensitive or acid-resistant. This yields useful information on the bond strength of the cement adhesive with restoration. Acid-sensitive ceramics such as leucite, feldspar, and lithium disilicate bases are readily etched by acids and form different etch patterns. The high crystalline ceramic or acid-resistant ceramic does not result in formation of microporosities and hence require other methods to improve bonding of cement and ceramic. These types of ceramic include densely sintered alumina ceramics, glass infiltrated alumina and zirconia, and Y-TZP ceramics [19].

The dental ceramic is also stratified based on the fillers, dopants, and matrix material. Based on these parameters, dental ceramics are classified into three major categories: predominantly glass ceramic, particle-filled glass ceramic, and polycrystalline (non-glass) ceramic [2,3]. We will look into the properties and surface treatment process for each of these ceramic type as follows:

5.1. Predominantly glass ceramic

This form of ceramic has been predominantly derived from the silicon oxide, feldspar minerals, and aluminum oxide. It has been used as the covering material over the metal or the ceramic coping and framework [3,20]. In addition, it has been used to construct the jacket crowns, on lays, porcelain veneers, and inlays. This form of ceramic is also highly esthetic, abrasion-resistant, and biocompatible, characterized by lesser mechanical strength as compared to other forms of ceramic. With a good cavity preparation and appropriate adhesive cement, it exhibits increased fracture resistance [21]. For the same reason, non-adhesive cementation process has not been indicated for the feldspathic ceramic [22].

5.1.1. Methods in conducting the adhesive cementation process using predominantly glass ceramic

Clinicians need to pretreat the "predominantly glass feldspathic ceramics" before doing the adhesive cementation process. They need to etch the intaglio surface of the ceramics with hydrofluoric acid solution (within 5 – 10% concentration), for about 1 min approximately. Doing this increases the surface area, cleans the surface and aids in micromechanical retention of the adhesive cements [23]. Application of silanes on etched surface increases the wettability of the cement and enables chemical interaction with the surface of hydroxylated porcelain and the resin matrix [24,25].

5.1.1.1. Silanation

Both silanation and etching processes are recommended in the routine practice, as few researchers have reported that there are higher rates of veneer failure when the ceramic has been silanated and air-abraded but has not been etched with the hydrofluoric acid [26,27]. For the process of silanation, two forms of silanes are available: Hydrolyzed and unhydrolyzed silanes. Hydrolyzed silanes are one-bottle systems with a shorter shelf life. However, if the contents in the bottle were

utilized after the date of expiry, it adversely affects the bond strength [27]. Unhydrolyzed form of silanes or inactive silanes was two-bottle systems utilized by the clinicians. Mixing of the ingredients is done before application, ensuring a more active form with a longer shelf life [28,29].

5.1.1.2. Etching system

Adhesive cementation process for dentin or the enamel necessitates the adhesive system use, followed by the resin cement application [4]. The adhesive systems can be either a self-etching system or a total etching system. Among these two-adhesive systems, self-etching system is the popular one among the dental surgeons as it is easier to use.

5.1.1.3. Resin cement

It is also vital to strictly follow the instructions provided by the manufacturers during the adhesive cementation process, including the use of the resin cement and adhesive combination of the manufacturers, as the researchers found certain incompatibilities between the simplified adhesive system and dual cure resin cement [30,31].

Resin cements are usually polymerized through chemicals, light or a process combining both light and chemicals. Light-polymerized resin is recommended when a thin and translucent ceramic is available. This is because it allows the light transmission through itself for reaching resin cement. In contrast to light-polymerized resin, dual-polymerized resin cement is indicated whenever the ceramic has been too opaque or too thick to enable light transmission through it [17]. Finally, polymerized resin cement with chemicals does not offer selection in terms of translucency or shade. Hence, the dual-polymerized resin cement is considered to be the most beneficial. In addition, the accessible areas might benefit from the use of light polymerization along with the dual-polymerized resin cement [32].

A self-adhesive resin cement has been introduced to reduce the steps in bonding and also enhance the ease of use. Such approach helps in combining the cement and adhesive in a single step. Using a self-etching primer before the application of cement is another approach developed. Dental surgeons might end up choosing these cements due to their simplicity and lower potential in application error. However, *in vitro* investigation of these cements showed that they bond to the dentin and enamel lesser than the effect demonstrated by the adhesive system and resin cement [33,34].

5.2. Particle-filled glass ceramic

This form of ceramic consists of several amounts, particle types, and glassy matrix. The particles inclusion has helped in improving the physical strength of ceramic. Reduction in the amount of glass and increase in the number of particles leads to increase in the strength of material. However, some esthetic and translucent properties are diminished due to this process. Based on its strength, several materials in the category can be utilized as the copings or veneering material [2].

5.2.1. Low-filled material

Low-filled material such as ordinary Portland cement (OPC) ("Jeneric Pentron, Wallingford, Conn") and IPS Empress Esthetic ("Ivoclar Vivadent") has been filled with the leucite. The physical strength of these materials has been relatively lower when compared to other filled glass material. This is one of the major reasons why these materials were indicated mainly for the veneers, outlays, and inlays and lower stress situations [3]. These forms of ceramics should be adhesively cemented for improving their strength [20]. The procedure of cementation is almost similar to the procedure described for predominantly glass ceramic.

5.2.2. Intermediate-filled material

Intermediate-filled material such as OPC 3G ("Jeneric Pentron") and IPS e-max Press ("Ivoclar Vivadent") has been reinforced with the lithium disilicate, and it has enough strength and good esthetic properties, which are sufficient to allow the use of this material for the single crown, veneers, and copings. These materials can be cemented either adhesively or non-adhesively, when it is utilized for the full-coverage restorations. Research studies have been reporting that there have been no significant differences between both types of cementations [35,36].

5.2.3. Methods in conducting the adhesive cementation process using particle-filled glass ceramic

Partial-coverage restoration such as the onlay, inlay, and porcelain veneer restoration requires adhesive cementation process for increasing the amount of fracture resistance and its retention. Full-coverage crown can be cemented either adhesively or conventionally based on their preparation design. Conventional method of cementation has been done with the conventional luting agent like resin-modified glass-ionomer cement, without requiring the intermediate agents. However, shorter, clinically non-retentive preparations must be adhesively cemented.

Another major area of consideration is the field control, as it is important for the clinicians to achieve an effective isolation in order to preserve the field free from saliva and any other contaminants while using the adhesive cements. The adhesive cementation technique for particle-filled glass ceramic is similar to procedure used for the predominantly glass ceramic. Nonetheless, the clinicians must modify the conditioning process of the intaglio surface of restoration for achieving the optimal adhesion. Manufacturers have been recommending to etch the intaglio surface of leucite-reinforced restoration with 10% hydrofluoric acid solution for 60 s approximately before the cementation process. Ceramic reinforced with lithium disilicate need to be etched with 5% hydrofluoric acid solution for about 20 s approximately. The dentists should then apply the silane, followed by a resin cement and an adhesive system, similar to procedure used for the predominantly glass ceramic.

More types of particle-filled glass have been made up of sintered core of the aluminum oxide infiltrated with the molten glass. These ceramics have a higher strength and fracture resistance with minimal content of glasses. They are also referred to as the glass-infiltrated aluminum-oxide ceramic. However, these materials are conventionally cemented rather than the adhesive cementation, because the etching glass with hydrofluoric acid does not increase the resin cement retention [37]. However, some investigators have been reporting that ceramic coating with the tribochemical silica and air-abrading the intaglio surface, followed by application of 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) (silane and phosphate monomer) before using the resin cement, might help in improving the bond to this ceramic type [38,39].

5.3. Polycrystalline ceramics

These forms of ceramics were densely sintered aluminum or zirconium oxide materials. They are characterized by the absence of glass in its composition [2,3]. These materials resist crack propagation as its atoms were packed into the regular arrays [40]. Polycrystalline ceramics have higher level of strength and toughness, and it can be utilized for framework and coping.

5.3.1. Methods in conducting the adhesive cementation process using polycrystalline ceramic

These ceramics were most commonly conventionally cemented but, in some circumstances, it might benefit from the adhesive cementation process. It is reported that air abrasion along with application of tribochemical silica or aluminium oxide followed by application of adhesive agents increases bond strength of resin cements [41]. The air abrasion process increases the surface area available for the bonding and also introduces the quasi-plasticity, microcracks or potential sites for fracture initiation. Hence, the utilization of the post-sintering surface treatment still remains controversial, although the low-pressure abrasion has been recommended [42].

Recent *in vitro* studies shows that treatment of zirconium oxide restorations with combination of 10- MDP (MDP Monomer) and tribochemical silica or using primer based on the carboxylate and phosphate functional monomer or a combination of metal primer and MDP, improves the bonding of resin based luting cements [43-45]. In addition, using primer containing MDP without the air abrasion improves the *in vitro* long-term adhesive property when compared to the conventional cementation procedure [42,46]. It has also been thought that such adhesion-promoting agent might produce the chemical bond to zirconium oxide [43-47]. Hence, the usage of air abrasion with the 50-μm powder of aluminum oxide powder at 7 pounds/square inch followed by the application of primer containing MDP before applying the resin cement

has been recommended whenever higher amount of retention is required.

6. Conclusions

Adhesive cementation is a complex technique for ceramic restorations that require a thorough understanding of adhesive principles and meticulous adherence to the clinical protocol to maximize bonding between the restorative material and tooth structure. The growing demand for esthetically pleasing restorations has led to the introduction and development of several dental ceramics. Dental surgeons should carefully consider not only the appropriate ceramic based on functional and esthetic demands but also the type of cement and cementation procedure for each system and clinical situation.

Furthermore, the success of adhesive cementation for ceramic restorations relies heavily on proper isolation, selection of appropriate adhesive systems and cements, and correct application techniques. Dental surgeons should continuously update their knowledge and skills to provide the best outcomes for their patients. In summary, adhesive cementation for ceramic restorations is an essential technique in modern restorative dentistry that can achieve highly esthetic and durable results. However, it requires careful consideration of multiple factors, including ceramic type, adhesive systems, and clinical protocol, to ensure long-term success.

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