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Method for Assessing the Bond Strength of Dental Restorative Materials — An Overview

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Abstract

Bond strengths achieved while testing in laboratories are the key for selection of adhesive systems. Longevity of a restorations can be predicted to some extent based on bond strength of adhesives. There have been several discrepancies within the reported bond strengths of various materials. Bond strength of the adhesive system is affected by a large number of factors, which makes the comparison among studies difficult. Throughout the years, laboratory evaluations have been the basis for clinicians to choose the adhesive systems in their daily practice. However the validity of bond strength tests to predict clinical performance of dental adhesives is yet to be justified. The realization of an adequate and valid method for assessing bond strength is a difficult endeavor. Different types of test have been utilized to assess the strength of a bond, which has its own advantages and disadvantages. Bonding strength is the strength required to rupture a bond formed by an adhesive system and the adherent. Often, the test involves the measurement of the shear and flexural bond strength of the adhesive system. This review focuses on aspects associated to various bond strength test methods used to test the adhesion between tooth and the restorative materials and their mechanics.

Keywords: Bond Strength Tests, Pus Out Bond Strength, Restorative Materials, Shear Bond Strength, Tensile Bond Strength

1. Introduction

Bond strengths achieved while testing in laboratories are the key for selection of adhesive systems. Longevity of a restorations can be predicted to some extent based on bond strength of adhesives. There have been several discrepancies within the reported bond strengths of various materials. Bond strength of the adhesive system is affected by a large number of factors, which makes the comparison among studies difficult[1]. Throughout the years, laboratory evaluations have been the basis for clinicians to choose the adhesive systems in their daily practice. However, the validity of bond strength tests to predict clinical performance of dental adhesives is yet to be justified[2,3]. The realization of an adequate and valid method for assessing bond strength is a difficult endeavor[4]. Different ways can be used to measure the bond strength. It is important to understand how the bond strength values are determined. Different types of test have been used to assess the strength of a bond, each with their own strengths and flaws[1]. Different companies manufacture products which can be compared at the same level. For such comparisons it's good to know which method of bond strength testing was used[4]. Bond strength is the strength required to rupture a bond formed by an adhesive system and the adherent. Hence the purpose of this review is to analyze the reliability of various methods of testing bond strength of adhesive between the tooth and restorative materials[5].

Adhesion is the attraction process between dissimilar molecular species, which have been brought into direct contact. Whereas the attraction between two similar

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molecules is known as cohesion. In situations involving an adhesive and a substrate, the overall bonding effectiveness can be determined by combination of adhesion and cohesion[5].

2. Bond

"A link between atoms in molecules or compounds is known as bond or chemical bond in chemistry."[4]

Types of Bond[6]

- Chemical bond- (Eg: In resin based materials chemical bonding occurs due to crosslinking of the polymer(s) within the material)
- Mechanical bond- (Eg: zinc phosphate, which does not bond chemically to the tooth surfaces and its bonding is possible only through mechanical interlocking between the restoration and the tooth)
- Combination of both

"A **chemical bond** is the link between atoms, ions, or molecules that forms chemical compounds." In ionic bonds the bond results from the electrostatic force of attraction between oppositely charged ions while in covalent bond it occurs through the sharing of electrons. Chemical bonds such as ionic, metallic and covalent bonds are classified as "strong bonds" or "primary bonds" whereas dipole-dipole interactions and hydrogen bonding are classified as "weak bonds" or "secondary bonds".[6]

"**Mechanical bonding** is a kind of bonding where the adhesive locks in the voids or pores of the surfaces or holds the surfaces together." In this type of bonding, physical locking occurs between the adhesive materials and the surface[6].

Application of Bonding in Dentistry[7]

1. Bonding of directly placed resin-based restorative materials
2. Bonding of indirectly placed restorative materials
3. Bonding of ceramic restorations
4. Bonding of amalgam restorations
5. Repair existing restorations
6. Treatment of cervical abrasion
7. Bonding of prefabricated and cast posts
8. Sealing of pits and fissures of posterior teeth
9. Reattachment of fractured tooth fragments
10. Reinforce fragile roots internally
11. Bonding orthodontic brackets
12. Bonding of periodontal splints

Bond Strength Testing

Bond is the adhesion between bonded surfaces. Bond strength is the strength needed to separate the bonded layers from each other. Bond strength is conventionally measured in terms of the amount of energy required to break the bond, in kJ/mol or kcal/mol[3].

A bond test is used to find out the ability of the bond strength of the adhesive system under stress. In other words, it is the ability of an adhesive to hold two materials together under stress. After the adhesive has been applied and allowed to harden, the bond strength of the adhesive system is tested by applying a force in an attempt to separate the material that has been connected by the adhesive. The force is applied to the bond until bond failure occurs[5].

Purpose of Bond Testing

Bond strength tests are used for evaluating the bond strength of adhesives. The bond strength of a restorative material may be reflected as its "stickiness" which depends on various factors. These factors include the type of load the bond experiences, the environmental conditions at which the test is done and the direction of the load. The of bond may require more shear force to be broken than the tensile force application[6].

Types of Bond Strength Test[8]

Different methods for bond testing are available. Tensile, shear, torsional, Impact, and pull out tests are the common methods used in dentistry. Under a given direction or type of stress the bond test is used to evaluate the bond strengths of adhesives. Bond testing can be done in two forms, either the ability of the adhesive which when applied as a type of coating on the surface material to remain in contact with the substrate when force is applied or as its capability to hold the substrates together while under stress when applied between two rigid substrates.

Static tests and dynamic tests are the two types of testing methods used for bond strength tests.

2.1 Static Tests

Static tests are more commonly used tests. It utilizes the application of forces to test a stationary sample.

These are of two types: -

- Macro tests which are used to measure the bonded area more than 3 mm
- Micro tests which are used to measure the bonded area smaller than 3 mm

2.1.1 Macro Testing

There are three different types of macro tests: shear bond strength tests, tensile bond strength tests and push-out bond strength tests.

Macro Shear Bond Strength Test (SBS)

For evaluation of new adhesives these tests are most frequently used technique. Shear bond strength tests "the maximum stress that a material can withstand before failure in a shear mode of loading." In these tests, shear loaded is done on the adhesive until it fractures. SBS testing is the simple and easy approach of testing as the specimens require no additional manipulation or preparation after bonding of the substrate and the adhesive.

The disadvantage of SBS is that it applies a lot of force on the tooth sample (bonded material), which might get fractured before the failure of adhesives. This can question the validity of results into between the failure of adhesive system and the fracture of the tooth substrate.

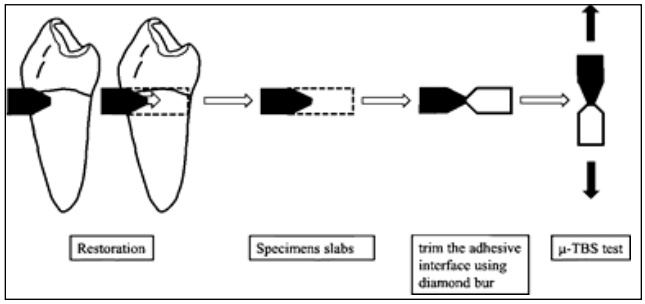


Macro-tensile Bond Strength Test (TBS)

Tensile bond strength test is less commonly used than shear bond strength. This method is used for evaluation of the bond strength of cement to metal alloys and ceramics in dentistry.

In tensile bond strength tests, after the specimen is loaded into the testing machine and held in place, a force is applied perpendicularly to both the sides of the sample which prevents its bending.

The advantage of TBS testing over SBS test is the uniform distribution of stress in the test. This provides a more exact information of the force required to break the bond.



Push-Out Test (PO)

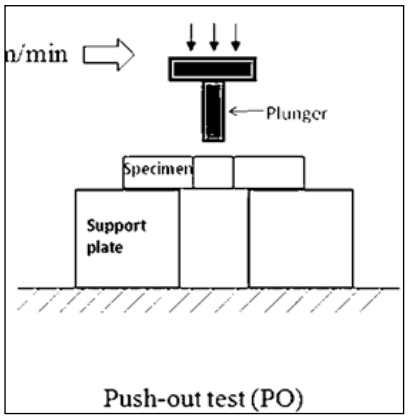
These tests are used to evaluate the bond strength between dentin and adhesives. Examples include, bond strength testing of posts luted in root canals and root canal sealers.

With this method, a tapered cylindrical hole is punched into a 1–2mm thick dentin slice by researchers. The inside of the hole is filled with the restorative material after coating with adhesives.

These tests provide information about the bond failure which occurs because of removal of the restorative material. The bond fails parallel to the interface between the material and the dentinal surface. This simulates clinical conditions better than shear bond strength tests. Sample preparation and method of testing push out bond strength are extremely time-consuming, and results replications are complicated.

2.1.2 Micro Testing

Micro tests are used to test small areas in specimens. Micro tensile, micro push-out and micro shear testing are the three methods of micro tests



Micro Shear Bond Strength Test (μSBS)

Micro shear bond strength test was first introduced in the year 2002. Specimens required for μSBS testing are small and multiple specimens can be prepared from one tooth. The test provides a uniform technique and eliminates parameters that affects the results of bond testing. It is typically used for specimens as glass ionomers, enamel, or other properties of the restorative materials that are fragile for micro tensile bond strength testing. When compared to traditional SBS, micro shear bond tests are considered to be less relevant.

Micro-tensile Bond Strength Test (μTBS)

Although it requires extensive specimen preparation and are technique-sensitive, micro tensile bond strength tests are efficient and have advantages than shear bond strength tests.

The advantage of this technique is that more uniform load is applied at the interface and bond failure occurs entirely at the bonded area making μTBS tests more accurate. These tests are not reliable to measure the bond strengths lower than 5MPa.

Micro Puch Out Test (μPO)

These tests are the variation of the macro push out test. It has to be investigated completely as other approaches. Bond strength measurement of luted fiber posts are done using this method. The specimen prepared for the test are dentin disks of 1 mm or less in thickness. Its accuracy is still undetermined as it usually results in values higher than that of normal push-out methods.

2.2 Dynamic Tests

These are the accurate reflection of clinical situation since a bond rarely undergoes stationary loading. Long-term effectiveness of adhesives is better provided by these fatigue tests. Having the advantage of more clinical replication, dynamic tests are not frequently used because these tests take more time and technique sensitive when compared to static methods of bond strength tests. No standard method of testing adhesives' bond strength has been made available by today. That is why dynamic methods of bond strength testing are difficult to replicate or quantify.

There are numerous varieties of dynamic tests which are present. This includes micro and macro shear, micro tensile, micro rotary, macro tensile and 3 and 4 micro point bend methods.

Factors that can Affect Testing

Bond-strength testing can be affected by various other factors in addition to the methodologies used for assessment.

The composition of tooth plays important role. Bovine dentition has dentinal tubules which are close to the pulp and have larger diameter. This can influence the validity of test methods regarding human teeth. The test results can be affected by the type of tooth tested in human beings. For example, third molar or teeth which have carious lesions can affect the bond-strength values.[9,10]

As the surface area increases the bond strength decreases. Hence, the results can get affected by the size of specimen.

Higher bond strengths have been displayed by adhesives higher dentin which are in the superficial layers, while as the dentin deepens, the bond strength lowers down.

Additionally, pressure in pulp, properties of restorative materials, Mechanical testing machine configurations and errors by operator can all affect the results in testing.

However immediate bond strength can be simply measured, determining the long-term bond strength is difficult because of the potential diminishing effectiveness. Although aging factors such as mechanical loading, thermocycling, enzyme degradation and water storage are used in lab testing, these situations might not simulate the clinical situations to which adhesives are exposed. Hence, clinical behavior cannot be aligned with the lab results[11].

Assessment of Tests

The bond strength of adhesive is an essential factor in success of restoration, investigators advise that the analysis of bond strength should be combined with other factors such as bond durability, gap evaluation and micro leakage tests and should be taken into consideration.

The consideration for clinicians is to assess a material's performance in long run over the data which is presented by the manufacturers' 24 hours lab test reports. With the limited available data, the adhesives with claims to have a very durable and strong bond strength have shown degrading bond strengths in long term aging experiments[12].

3. Conclusion

Every effort should be made to design a test methodology which is standard for evaluating the bond strength test since many factors which are not under control can cause variations in measurement of bond strengths. Direct inferences on the clinical behaviour of restorative materials should not be made from the values obtained from currently available bond strength testing methods however they can be used for comparison of materials under the same laboratory settings. Micro-tensile bond strength tests provide many advantages over the shear tests as the distribution of forces in shear and micro shear tests is not uniform and the stress gets concentrated at the substrate area. However micro tensile bond strength testing methods are technique sensitive and labor intensive. Presently, the challenge in restorative dentistry is to know the durability and clinical performance of adhesives and making the interface between adhesive and tooth more resistant to aging, making the restoration more predictable in the long run.

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