

Bonding of Fractured Fragments using Various Bonding Materials as a Treatment Modality in Cases of Vertical Root Fracture- A Systematic Review

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ABSTRACT

Introduction: Vertical Root Fracture (VRF) is third most common factor leading to extraction of root canal treated tooth. It has a longitudinal orientation. This occurs due to reduction in structural integrity and dehydration of dentine. Most common treatment includes extraction of the teeth. Other modality is amputation of involved root in molars. Various materials can also be used for bonding of the fragments.

Aim: To compare and evaluate the effectiveness of dentine bonding systems in re-attachment of fractured root.

Materials and Methods: The present systematic review included a comprehensive search of last 10 years was performed in the systematic electronic database PubMed. In-vitro laboratory studies that evaluated the microtensile bond strength and fracture resistance of multiple dentine adhesive systems and compared them in human and/or animal teeth in which VRF had

occurred were included. A total of 16 non duplicated studies were retrieved in the systematic search.

Results: Out of 16 studies four studies were included in the systematic review. One study assessed the bond strength of the adhesive using table top testing machine. Two studies assessed the microtensile bond strength using stereo microscope and one study assessed recurrence of the fracture using Instron Machine. The studies demonstrated large variability among methodology used for evaluation. In one study, acid phosphate monomer showed highest microtensile bond strength ($p < 0.05$), and in another study Refracture (RF) occurred easily in samples bonded with Glass Ionomer Cement (GIC) as compared to those bound with Perma Bond and Gluma ($p < 0.0003$).

Conclusion: From the present study's analysis, dual cure adhesive resin cement either reinforced with polyethylene fibres or glass fibres, and glass ionomer cement may increase the fracture resistance of bonded tooth.

Keywords: Adhesive systems, Longitudinal fractures, Re-attachment

INTRODUCTION

Vertical Root Fracture has longitudinal orientation and originates from apex of the root and propagate to the coronal part of the tooth [1]. It is third most common factor leading to extraction of root canal treated tooth [1]. Changes occurring in Root Canal (RC) treated tooth are decreased stiffness and also leads to decreased fracture resistance. This occurs due to reduction in structural integrity and dehydration of dentine. In such cases endodontic crowns are better to be used instead of full crowns [2]. Post and core is also the better restorative modality in cases of RC treated tooth [3].

The VRF leads to poor outcome of the tooth. Complete root or a part may be involved in the fracture [4]. It may extend to only one or both sides of the root [4]. Diagnosis of VRF is quite difficult. It is likely similar to the periodontal disease or the failed endodontic treatment [1]. In multi-rooted teeth, fracture is commonly oriented in buccolingual direction. In anterior teeth also it is directed buccolingually [4]. VRF can be classified as: initiating from the coronal tooth structure and one initiating from the apex. It can also be classified as complete and incomplete VRFs [4]. VRF presents with multiple clinical features, thus making it difficult to diagnose. It presents delayed signs and symptoms. Clinical and radiographical features include deep periodontal pocket, pain, j-type radiolucency and sinus tract. Most common treatment includes extraction of the teeth [5]. Other modality is amputation of involved root in molars. Bonding of the fragments can also be done [5]. Sugaya T et al., developed the method which includes atraumatic intentional extraction followed by rotational replantation of the tooth [6]. Adhesive resin are used to restore the tooth. Extraction of fragment helps to clear granules. Rotational replantation creates contact in the

crack and healthy periodontal tissue [7]. Various materials can be used for bonding of the fragments. It includes Methyl Methacrylate (MMA) based resin material, dual cure composites and GIC [7-9].

The purpose of this systematic review was to assess the success of dual cure composite with three adhesive systems [Clearfil SE Bond (SE), Tokuyama Bond Force (BF) and Clearfil DC Bond (DC)], MMA based adhesive resins, dual cure resin cement with polyethylene fibres and glass fibres, GIC, resin and Cyanoacrylate cement to bond fractured fragments. The hypothesis is none of the above bonding materials have successful results in treatment of VRF.

MATERIALS AND METHODS

This systematic review was conducted according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement. The studies were selected according to the inclusion and exclusion criteria. All abstracts and full texts were reviewed. None of the manuscript author was contacted during this process. Disagreements between authors were evaluated and the studies were eliminated through discussion among researchers until a consensus was reached.

Inclusion criteria: The eligibility criteria considered in-vitro laboratory studies that evaluated the microtensile bond strength and fracture resistance of multiple dentine adhesive systems and compared them in human and/or animal teeth in which VRF has occurred. The studies in the review were included from year 1993-2013 and duration of systematic review was two months.

Exclusion criteria: Studies that considered extraction as a treatment option for VRF were excluded.

Search Strategy

A systematic search without restrictions was performed by two independent reviewers in the electronic database PubMed without restriction on year of publication. No filters or limits were applied in the searches. The selection of the descriptors was based on the most cited terms in previous publications related to this theme. The Boolean operators 'AND' and 'OR' were used to create the keywords search [Table/Fig-1]. The keywords used were "VRF," "re-attachment of fragment", "material for bonding". The search details were "VRF (all fields) AND re-attachment OR bonding (all field) AND bonding material (all field)."

S. No.	Search strategy	Results
1	{ "vertical" (All Fields) OR "verticality" (All Fields) OR "vertically" (All Fields) OR "verticals" (All Fields) } AND { "plant roots" (MeSH Terms) OR ("plant" (All Fields) AND "roots" (All Fields)) OR "plant roots" (All Fields) OR "root" (All Fields) } AND { "fractur" (All Fields) OR "fractural" (All Fields) OR "fractures" (All Fields) OR "fractures, bone" (MeSH Terms) OR ("fractures" (All Fields) AND "bone" (All Fields)) OR "bone fractures" (All Fields) OR "fracture" (All Fields) OR "fractured" (All Fields) OR "fractures" (All Fields) OR "fracturing" (All Fields) } AND { "bonded" (All Fields) OR "bondings" (All Fields) OR "bonds" (All Fields) OR "object attachment" (MeSH Terms) OR ("object" (All Fields) AND "attachment" (All Fields)) OR "object attachment" (All Fields) OR "bonding" (All Fields) }	20
2	fractured" (All Fields) AND "root" (All Fields) AND "fragment" (All Fields) AND "bonding" (All Fields) AND ("dentine" (All Fields) AND "adhesive" (All Fields)) AND "vitro" (All Fields)	0
3	(VRF) AND (replantation) AND (bonding) AND (dentine adhesive)	1

[Table/Fig-1]: Search strategy in PubMed Database.

Selection of the Studies

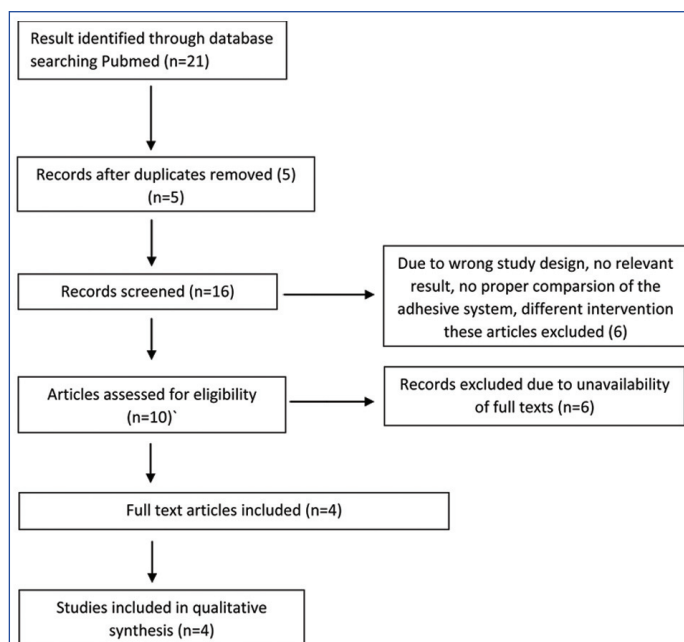
Two independent authors selected the studies, examining the retrieved titles and abstracts according to the search strategy. When it was not possible to judge the studies by title and abstract, full text was obtained for the final decision. This review included in-vitro studies. For this reason, the Patient Intervention Comparison Outcome (PICO) system was adapted: population (studies conducted in human/animal extracted teeth), intervention (evaluation of success of material used for the treatment), comparison (between the materials used), and outcomes (success rate of the material). Disagreements on inclusion criteria were solved by consensus with a third author following the predefined inclusion criteria. Studies that appeared to be duplicated in the database search were considered only once.

Quality Assessment of Studies

In second step full text of the chosen articles were read out for data extraction and quality assessment was done as per Oral Health Assessment Tool (OHAT) by two independent reviewers (PC, KR) [10,11]. In cases of difference between reviewers, the third senior reviewer (MC) clarified the discrepancy. Flow chart for this systematic review is shown in [Table/Fig-2].

In the beginning, 21 articles were selected which included bonding of fractured root fragment with the dentine adhesive. Five articles were excluded due to duplication. Out of remaining 16 articles, six studies were excluded due to wrong study design, no relevant result, no proper comparison of the adhesive system, different intervention and six more articles were excluded due to unavailability of full text. Hence, only four articles were selected [Table/Fig-2]. Title, abstract, a scientific context based on bonding of fractured root fragment with dentine adhesive was included. Also, rationale, objectives hypothesis, methodology showing study type was incorporated. Intrusion, statistical analysis, evaluation period were also used and main results were extracted from each experimental study.

In this study, after quality assessment for risk of bias was done by three independent reviews and by OHAT tool, it was found that all studies included low risk of bias [Table/Fig-3] [7-9,12].



[Table/Fig-2]: PRISMA flow diagram.

Study variables	Waidyasekera K et al., 2012 [8]	Nurrohman H et al., 2011[7]	Kumar BS et al., 2013 [12]	Friedman S et al., 1992 [9]
Sample allocation	90 bovine teeth	66 single rooted lower premolars	60 single rooted mandibular premolars of patients between 15-20 years of age	36 single rooted teeth
Experimental conditions across study groups.	No	No	No	No
Was research personnel blinded to the study groups?	No	No	No	No
Were outcome data complete without attrition or exclusion from analysis?	No	No	No	No
Are we confident in the outcome assessment (including blinding)	No	No	No	No

[Table/Fig-3]: Quality assessment of the studies [7-9,12].

Research question: Is bonding of the fractured fragment using various bonding material the effective treatment modality in cases of VRF?

RESULTS

Search findings and study characteristics: A total of 21 articles were found. After screening the titles and the abstracts of the identified studies, four studies were included in the full-text analysis. No additional relevant studies were found from hand searching. The four studies included were in-vitro studies. As the articles were heterogeneous in design/methodology and contained disparate data types, quantitative analysis was not possible and a qualitative systematic review was performed.

The initial screening of the retrieved studies was conducted using titles and abstracts. The corresponding full text was read when the results were unclear. The authors independently evaluated the studies and discussed the results until a decision was reached by consensus. The outcome of the included studies is mentioned in [Table/Fig-4]. The performance of the included articles on the JBI The Joanna Briggs Institute Critical Appraisal tool (JBI) is presented in [Table/Fig-5] [13].

Author and year	Type of study	No. of teeth selected	Intervention	Comparison	Outcome	Method
Waidyasekera K et al., 2012 [8]	In-vitro	90 bovine teeth	Type- resin bonding material Sample size- 25 each in three groups for micro tensile strength testing and 15 teeth for ultramorphology of adhesive/dentine interface of bonded root fragments under SEM.	1. Dual cure core build up material (clearfil DC core automatrix) And one of the three adhesive systems. • Clearfil SE bond (SE) • Tokuyama bond Force (BF) • Clearfil DC bond (DC)	Acid phosphate monomer (SE) showed highest microtensile bond strength ($p<0.05$). BF yielded higher bond strength than DC.	Table top testing machine
Nurrohman H et al., 2011 [7]	In-vitro	66 single rooted lower premolars	Type-MMA based adhesive resin. Sample size- randomly divided in three groups	1. Super bond C and B 2. M-bond or M-bond II	• MB or MB-II yielded higher microtensile bond strength to cervical dentine than to apical dentine in comparison to SB ($p<0.05$) • Substantial reduction in μ TBS was found for MB and MB II after one year, whereas no significant difference was found for SB ($p<0.05$)	Handy type universal testing machine (EZ-Test; Shimadzu, Kyoto, Japan), stereomicroscope (Nikon SMZ1000; Nikon, Tokyo, Japan) and scanning electron microscope
Kumar BS et al., 2013 [12]	In-vitro	60 single rooted mandibular premolars of patients between 15-20 years of age	Type- resin bonding agent Sample size- 15 each	1. Dual cure resin cement (RelyXU100) 2. Dual cure resin cement and polyethylene fibre (ribbond) 3. Dual cure resin cements and glass fibres (stick net) 4. Control group	RelyXU100 showed lowest fracture resistance. Control group showed highest fracture resistance followed by ribbond group and stick net group.	Stereomicroscope (Olympus S2X12)
Friedman S et al., 1993 [9]	In-vitro	36 single rooted teeth	Type- acrylic resin+cement Sample size- 12 each	1. Glass ionomer cement 2. Composite resin (Gluma bond) 3. Cyanoacrylate cement (Prerna bond)	RF occurred easily in samples bonded with glass ionomer cement as compared to those bound with perma bond and gluma ($p<0.0003$)	Instron machine

[Table/Fig-4]: Reported outcome of the re-attachment of the vertically fractured root using resinous material.

Parameters	Waidyasekera K et al., 2012 [8]	Nurrohman H et al., 2011 [7]	Kumar BS et al., 2013 [12]	Friedman S et al., 1992 [9]
Was there a control group?	No	No	Yes	No
Were there multiple measurements of the outcome both pre and post the intervention/exposure?	No	No	No	No
Was follow-up complete and if not, were there differences between groups in terms of their follow-up adequately described and analysed?	NA	NA	NA	NA
Were the outcomes in any comparisons measured in the same way?	No	Yes	Yes	No
Were outcomes measured in a reliable way?	Yes	Yes	Yes	Yes
Was appropriate statistical analysis used?	Yes	Yes	Yes	Yes

[Table/Fig-5]: Performance of the included articles on the JBI (The Joanna Briggs Institute Critical Appraisal tools) critical appraisal checklist for quasi-experimental studies [13].

NA: Not applicable

DISCUSSION

Tooth with VRF is difficult to treat with conventional treatment like root canal treatment. Multiple modalities are tried to preserve completely cracked tooth. These modalities include root resection in multi-rooted teeth and extraction in single rooted teeth [12]. Root fracture reconstruction has been tried with various adhesive cements [12]. This study aims in analysing various bonding or adhesive materials for their success in bonding the fractured root fragments and their ability to resist RF.

Waidyasekera K et al., in the study used different materials for bonding of fractured fragments: Dual cure resin composite Clearfil DC Core Automatrix, two-step self-etching adhesive Clearfil SE Bond, one step self-etching adhesive Tokuyama Bond Force or one step dual cure self-etching adhesive Clearfil DC Bond. The samples used for the study included bovine root fragments. The study was conducted to observe micro-tensile bond strength or ultimate bond strength of the materials used. The bond strength is affected by the dentine adhesive system to be used and water storage time. The result was statistically analysed by two-way ANOVA and Post-hoc test. Out of the above materials used Clearfil SE Bond showed highest microtensile bond strength of 59.7 ± 7 irrespective of time for water storage. The initial micro-tensile bond strength was maintained even at one year of water storage of the specimens in case of Clearfil SE Bond. Tokuyama Bond Force showed reduction in the bond strength of 40.4 ± 2.41 at six months of storage in water. Clearfil DC Bond showed least microtensile bond strength of 35.3 ± 4.9 . In case of resin material Clearfil DC Core Automatrix, the bond strength is affected only by the mode of curing. Water storage has no effect on the bond strength of resin. Resin incorporates well in dentinal tubules. It also infiltrates well in interfibrillar spaces and thus maintain the bond strength [8].

Nurrohman H et al., in their study evaluated micro-tensile bond strength (μ TBS) of MMA based adhesive. The materials used were Super Bond (SB) C and B, M-Bond or M-Bond II. The bond strength was evaluated in cervical and the apical region. The results were obtained statistically using three-way ANOVA test. Two-way ANOVA test followed by Dunnett's T3 Post-hoc test was carried out for each material. Value of significance kept was at $\alpha=0.05$. As stated earlier the bond strength is affected by the dentine adhesive system to be used and water storage time. No significant difference was seen in μ TBS of SB in cervical and apical region i.e. 21.0 and 22.1 at the end of one year. Water content of dentine in cervical region increases with increase in tubule diameter and density. The initiator in SB uptakes O_2 and H_2O . This leads to Free Radical Polymerisation (FRP) of monomers in resin. This stabilises bond strength of SB in various regions. A decrease in μ TBS was found with of both self-etching systems M-Bond and M-Bond II with the mean value of 15.7 and 13.5 at the end of one year. This is due to

increased content of hydrophilic like phosphoric acid monomers in MB and MB II primers. This results in increased water sorption. This decreases hydrolytic stability of the interface and thus decreased bond strength [7].

Kumar BS et al., conducted in-vitro study. They evaluated fracture resistance in vertically fractured root bonded with fibre reinforced composites. The teeth were intentionally fractured. They were rebonded with dual cure resin cement (RelyXU100), Dual cure resin cement and polyethylene fibre (Ribbond) and Dual cure resin cements and glass fibres (stick net). Vertical fracture resistance was calculated by one-way ANOVA and Tukey Post-hoc test. In fibre composites the mechanical properties depend on the direction of fibres in the matrix. Unidirectional and continuous fibres provide stiffness and strength to the material towards the fibre orientation. Thus ribbond showed higher resistance to fracture with the value of 328.1 N. This is because Ribbond fibres adhere to root dentine as well as the resin part. In comparison stick net fibres and RelyXU100 fibres forms clusters in canal space. In this system only resin part has the adhesion property with decreases the fracture resistance [12].

Friedman S et al., in their study calculated forces leading to RF of the already bonded fractured root fragments. In the study, he also evaluated the bonding strength and the fracture resistance of the material used for bonding. This is the in-vitro study. The samples were mounted in Instron Machine. The forces were made to exert vertically till the fracture occurred. The force fracturing the root (F), root surface area (A) was measured. The fractured fragments were attached with Ionos bone cement, Permabond 910 cyanoacrylate adhesive and Gluma bonding system. The samples were then stored in wet sponge. The roots were RF one week later. The force required for RF of roots was measured. The values were statistically calculated by Kruskal-Wallis, one-way ANNOVA and Mann-Whitney u test. Thus the results showed that the RF force in the samples bonded with Ionos cement was less i.e., 15.09 lb as compared to samples bonded with Permabond with the value of 38.42 lb and Gluma with 31.13 lb. RF/A ratio was less for Ionos cement i.e., 22.11 mm² in comparison to Permabond with 54.41 mm² and Gluma with 41.21 mm². The results with Permabond and Gluma were not statistically significant [9]. Thus, the above hypothesis was proved to be wrong as dual cure composite resin with resin adhesive system, MMA based resin (SB C and B) showed significant results for bonding in cases of VRF.

Limitation(s)

The studies included in this systematic review did not have common materials to compare. Hence, it is difficult to give an appropriate

conclusion. Studies with common parameter for comparison are required to come to proper conclusion. As these studies conducted were in-vitro, more in-vivo studies are required on the use of these materials in re-attachment of VRF.

CONCLUSION(S)

By reviewing the above studies, it is demonstrated that dual cure composite resin with resin adhesive system, MMA based resin (SB C and B) showed significant results for bonding in cases of VRF. Dual cure adhesive resin cement either reinforced with polyethylene fibres or glass fibre, and GIC can be used to increase the fracture resistance of bonded tooth.

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