Original Article

Evaluation of Shears Strength of Dowel Amalgam and Post-amalgam in Root Canal-treated Teeth

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Abstract

Introduction: Amalgam, which can be applied with or without dowel, is one of the commonly used restorative materials for core restoration in pulpless teeth. The current study aimed to compare the shear strength of amalgam cores with and without dowel. **Methods:** A total number of 20 recently extracted mandibular premolars were assigned to two groups of 10 equal specimens, including group I: dowel amalgam restored with prefabricated dowel and amalgam core and group II: post-amalgam restored with amalgam as a post and core. All Specimens were stored at humidity and room temperature prior to testing. Each specimen was carefully placed in a special jig at a 90-degree angle to the axis of teeth and subjected to a load that was recorded in kgf on a Zwick/material testing machine at a crosshead speed of 0.5 mm/min until failure. Independent T-test was used to compare the results. **Results:** Based on the obtained results, the mean shear strengths were reported as 37.7±10.49 and 16.8±6.37 kgf for dowel amalgam and post-amalgam, respectively. There was a statistically significant difference between the two groups ($P<0.0001$). **Conclusions:** The obtained results demonstrated a significant difference between the two groups. Accordingly, the use of dowel with amalgam to restore pulpless teeth has higher compressive strength, as compared to the use of post-amalgam.

Keywords: Dowel amalgam, Post Amalgam, Shear strength

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Introduction

The type of restoration that should be applied to a root canal-treated tooth mostly depends on the extent of coronal destruction and the type of tooth. In general, in a pulpless tooth, the lost tissue is restored with core (1), and a dowel core and a crown should be made to retain, protect, and reinforce the pulpless tooth.

Several methods have been introduced for dowel fabrication, including cast and prefabricated dowel. Dowel retention and core stability are of utmost importance in preventing fracture in pulpless teeth with extensive destruction(1,2). The dowel should be utilized in teeth only if the roots are adequately long, bulky, and straight. Great care should be taken while selecting a suitable restoration material for teeth without any residual crown structure. The encirclement of 1-2 mm of peripheral vertical axial tooth structure within the walls of the crown creates a Ferrule effect around the tooth and protects the tooth against fractures(1). Aykent Fet al. (3) investigated the effects of ferrule effect on the fracture strength of crowned teeth restored with amalgam core and prefabricated dowel. They observed the highest fracture strength in the group with a 2 mm axial wall above the Cemento Enamel Junction (CEJ).

Amalgam is still the material of choice for the core restoration of posterior teeth (4). Gorucu J et al. (5) compared the shear bond strength of different materials, including build-up amalgam, Filtek Z250, and Filtek P60 composites. He detected the highest shear bond strength in packable composite (P60); nonetheless, no significant difference was found. In a laboratory study, Kovarik RE. (6) revealed that 67% of amalgam cores withstood a pressure of 75 pounds in a one-million-time cycle, while only 17% of composite resin cores resist this pressure. In a laboratory study to investigate the fracture resistance of different materials for the core, Sangwan B et al. (7). reported that the posterior composite group indicated higher fracture, as compared to amalgam group. .

Due to the weakened internal and external tissues, reduced moisture, fragility, and less resistance against stress, root canal-treated teeth should be reinforced by intra-root restorations before fixed prosthodontic treatment. This technique improves resistance against horizontal and vertical forces and preserves residual tooth structure (1, 2).

Shear strength is the fracture strength of material against shear forces or the ability of the material to resist shear forces until reaching the point of fracture. This force is exerted by a chisel-shaped bar perpendicularly to the longitudinal axis of the specimen. The maximum force required for the fracture is considered the shear bond strength(8).

- In the present study, the use of amalgam with the prefabricated dowel is named as dowel amalgam group and amalgam utilization without dowel that is amalgam packed into the root canal and core space is named as post-amalgam (1).

- With this background in mind, the current study aimed to evaluate the shear strength of dowel amalgam and posts-amalgam and compare them. In case of detecting a difference between them, a restoration with more shear strength would be used for root canal-treated teeth. This saves patients hassle, time, and money since these two methods do not require resin pattern fabrication and lab process for custom cast dowel cores.

Materials and Methods

For the purpose of the current study, a number of 20 intact mandibular premolars which were extracted for orthodontic, periodontal, or prosthetic reasons were selected (4, 9, 10). All teeth had a closed apex, a healthy crown, and root with an average length of 23mm. For sterilization, the teeth were immersed in 5% buffered formalin for 2 h (11); thereafter, they were cleaned and kept in distilled water to prevent drying (4, 11, 12).

After radiographic evaluation, the samples were mounted vertically up to CEJ in the middle of boxes made of gypsum stone with a dimension of 3*3 cm and a height of 4cm(Figure 1). The Access cavity was then prepared for root canal treatment. The teeth were manually prepared with the step-back technique using K-files (MAF No.45), normal saline was used for irrigation. Finally, after drying the canals with Paper Points, canals were obtruded by lateral condensation technique and using Gutta Percha and AH 26 sealer (Germany Konstanz, Dentsply - De Trey, Sealer) (9, 10).

After root canal treatment, the preparation of dowel core started by preparing the coronal tooth structure for the crown that will be definitive restorations. Therefore, the occlusal reduction was up to 4 mm that is 2mm for amalgam core and 2mm for metal-ceramic restoration (MCR) clearance, and the remaining tissue was evaluated at the end so that the ratio of thickness to height (T / H) was regarded as 2 to 1 (2/1). The finish line of crown preparation was 2 mm apical to the dowel-core margin all around tooth surfaces (1, 7, 11).

The samples were randomly assigned to two groups of 10 and the teeth canal was prepared to create a dowel space with a length of 9 mm and a diameter of 1.5 mm (10, 12, 13). Therefore, for each specimen, gutta-percha was removed from the canal to a depth of 9 mm using Peeso reamer No. 2. Subsequently, to create dowel space with a diameter of 1.5 mm, Peeso reamers No. 3, 4, and 5 were used to the inner depth of the canal, respectively (11,12). After irrigating and cleaning, the dowel space was ready for the next step which was the fabrication of dowel amalgam or post-amalgam.

A: The fabrication of samples for dowel amalgam group (Group A)

Stainless steel prefabricated dowel (Conical Assortment, Swiss, Gold Plated Screw dowel Long no.) were selected in the proper diameter and length. Zinc phosphate cement (Harvard Cement, Germany) was mixed according to the manufacturer instructions. Walls of the dowel space were coated with cement by a file No. 40, the dowel was also coated with cement, and it was then placed inside the dowel space. Thereafter, it was pressed with a fixed finger for 5 min to set the cement, and excessive cement was then removed by an explorer. It took at least 1 h for the cement to be fully set (4, 14, 15). After the placement of the matrix band, the amalgam (DENTAM TM ^ TM, u.k., 45% Ag, 24% Cu, 31% Sn) was placed inside the mold using the amalgam carrier and was condensed manually. The matrix band was carefully removed after the initial set of amalgam and samples were kept in a semi-humid environment for at least 24 h for the final set of amalgam (8, 14, 16).

Amalgam cores were prepared by a diamond bur (Diatech Diamond Swiss co.) in the form of identical cylinders with a height of 5 mm and a diameter of 6 mm. Subsequently, the samples were stored in humidity and room temperature until the measurement stage (8, 13, 14) (Figure 2).

B. The fabrication of samples for the post-amalgam group (group B)

In this group, the same matrix band was applied to each tooth as in the previous group, and the amalgam was first condensed into the post space by a thick endodontic plunger, and the amalgam of the core was immediately condensed as in the previous group(4, 17, 18) (Figure 2).

It is noteworthy that all the above procedures were evaluated by radiography (Figure 3).

The prepared samples were transferred to the Zwick/Material Testing machine (Zwick Roell Germany) using metal Fixture. Shear force was applied to the contact point of the amalgam sample with the tooth by a metal blade at a speed of 0.5 mm/min. This force was applied perpendicular to the longitudinal axis of the tooth and the required maximum force was used to break the sample considering Shear Strength (SS) of each sample (8, 19, 20) (Figure 4).

When a crown is placed on a core, the shear strength is completely different due to variations in stress distribution since crown plays a key role in the increase of fracture strength of endodontically treated teeth owing to the ferrule effect. In this regard, it may influence the results of the current study; therefore, the samples were tested without the crown in order to avoid the ferrule effect.

After data collection and measurement of mean and variance of two groups, the independent T-test was used to compare the obtained results. A P-value less than 0.05 was regarded as statistically significant.

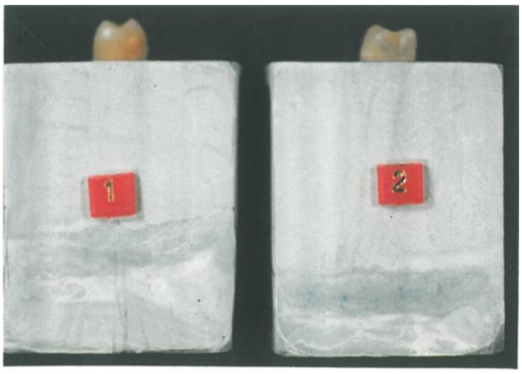

Figure 1. Specimens in gypsum stone boxes

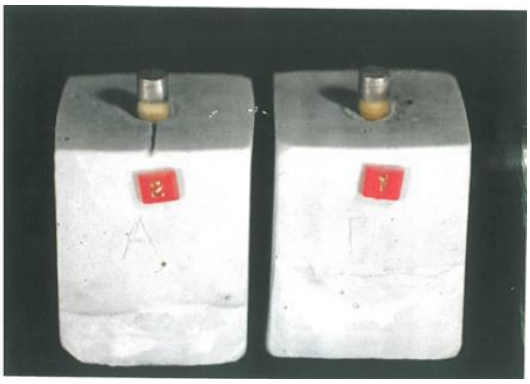

Figure 2. Prepared samples for measurement after amalgam core reconstruction

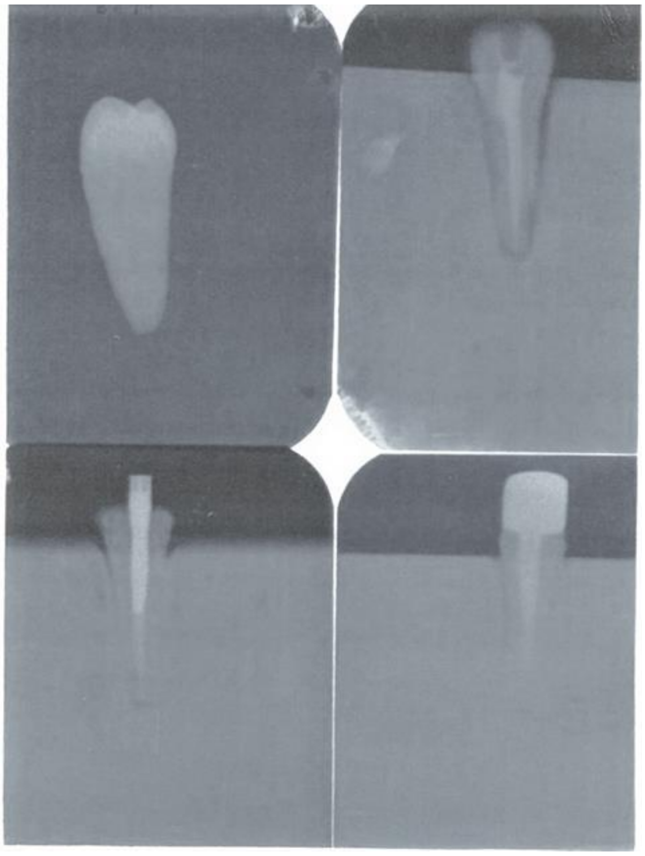

Figure 3. Radiography evaluation of the tooth, randomized controlled trial , proper dowel, and sample

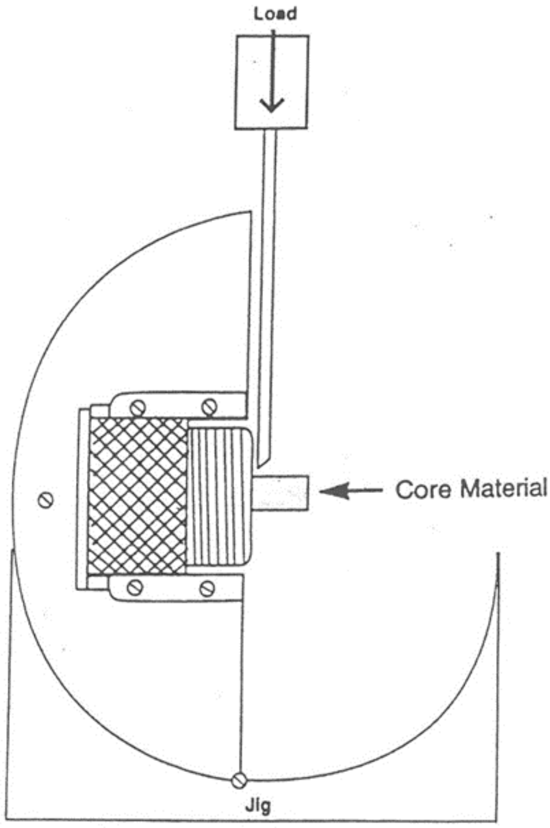

Figure 4. Schematic image of the sample in the fixture specific for the tester device and the angle of exerted force

Results

The collected data from the two groups of 10 samples who were selected by the consecutive method were analyzed. The means, standard deviations, lower and upper bond of shear strength are presented in Table I. Data normality was investigated using the Kolmogorov-Smirnov test. This test demonstrated that the distribution of shear strength is normal in dowel amalgam and post-amalgam groups (P=0.202; P=0.321). Moreover, the independent t-test was used to compare the means of two groups. The mean of shear strength was significantly different between two groups (P<0. 001). The minimum fracture strength for dowel amalgam was reported as 21kgf and the maximum was 58kgf; moreover, the mean force required to fracture the material of the dowel amalgam group was reported to be 37.7±10.49 kgf. The minimum fracture strength for post-amalgam was obtained as 10kgf and the maximum was calculated at 30kgf; in addition, the mean force required to fracture the material of the post-amalgam group was measured at 16.8±6.37 kgf (Table I).

Table I. Descriptive statistics and means comparison of shear strength

group	n	Mean	Standard Deviation	Minimum	Maximum	t-statistic	P-value
Dowel Amalgam	10	37.7	10.49	21	58	5.38	0.0001
Post-Amalgam	10	16.8	6.37	10	30		

Discussion

In the current study, 20 mandibular premolar teeth were prepared in two groups of 10 to determine and compare shear strength between dowel amalgam and post-amalgam. As evidenced by the results of the current study, the mean fracture resistance was higher in the dowel amalgam group (37.7±10.49 kgf), in comparison to the post-amalgam group (16.8±6.37 kgf). Kovarik RE.(6) suggested that when at least 2mm tooth structure kept below the core margin is considered ferrule, any material is possible for the core. Nevertheless, sometimes in clinics, the crown edges should be immediately below it in such a case. Moreover, the choice of material in these cases is considered a factor determining the lifetime of the restoration. When a crown is placed on a core, the shear strength is completely different owing to variations in stress distribution (1,). Burke F et al..(17) conducted a study to investigate different core materials and found that the highest fracture strength of the samples with anatomical form and pre-milled shape for complete crown preparation belonged to amalgam but with metal-ceramic crown preparation, amalgam had the highest percentage of reduction, and hybrid composite demonstrated the highest fracture strength in milled samples.. Crowns were used for all samples in a study carried out by Martinez-Insula et al. (11) entitled "comparison of fracture strength of pulpless teeth with a post and cast core with fracture strength of pulpless teeth with a carbon-fiber post and composite core". This led to an increase in tooth fracture incidence due to Shear forces, especially in the casting post and core group.

Maksimovskaya L.(14) in a longitudinal study which aimed at finding the right material for the direct restoration of root canal treated teeth proposed a dual-cure, including nanocomposite along with the fiberglass intra-canal post as a factor of significantly increased tooth strength and reduced marginal leakage In the mentioned study, no crown was used on the core; therefore, the variables were prevented from increasing, and the crown effect (ferrule effect) was also avoided (4,13. Along the similar lines, Fujimoto observed no significant difference between the tensile strength of post-retained amalgam core and composite 18). According to a study conducted by KaoEC. (19), prefabricated posts are mechanically retained inside the amalgam alloy due to their surface irregularities, and there is no chemical bond between the post and the amalgam; therefore, the posts act as voids in the restorative material.. It was in agreement with the results of the present study since there was a fracture between dowel and amalgam in dowel amalgam samples. Amalgam is stronger in bulk, and posts or pins reduce the volume of amalgam restoration when used with amalgam. It leads to stress concentration on specific points and line angles on contact surfaces between post and amalgam, which in turn, weakens amalgam core (4, 11). In a similar vein, the post-amalgam samples of this study, the amalgam core with a high volume, fractured in the contact spot with intra-canal amalgam post(i.e., a spot with the lowest fracture resistance), and the fractures were cohesive. However, in the dowel amalgam samples, despite higher fracture resistance, the amalgam cores had the most fractures at the contact surfaces with dowel (adhesive failure) indicating the stress concentration at these points and surfaces which confirms the results of the aforementioned studies.

According to a study performed by CohenBI et al. (4) the post and core set have the highest fracture resistance to forces exerted from 45-degree angles. Nevertheless, to investigate shear strength in this study, the highest fracture resistance was considered those exerted forces perpendicular to the longitudinal axis of the samples according to such researchers as LoCS et al. (8),Cohen BI et al. (20) , LevartovskyS et al.(21), and Madani M et al. (22),

The lack of adequate moisture in the root canal-treated teeth often reduces the fracture resistance of these teeth. This can reduce the elasticity of the residual root structure when drying the canal prior to dental filling with gutta-percha and also owing to the heat generated by rotating devices during post space preparation (12, 23,24).

The storage of amalgam core samples in moisture is also regarded as the Aging step. Although researchers considering thermocycling methods as the Aging step did not find any effect on the bond strength of adhesive agents, according to the study by Lo et al.(8) the shear bond strength increased at 37℃ in a group containing three prefabricated posts after 30 days of staying in normal saline. Nonetheless, no significant effect was observed in the group with no post under the same conditions. Better adaptation of amalgam to posts may have occurred as a result of the expansion and corrosion of amalgam in water during this period. Since the prefabricated posts are made of gold plated stainless steel, it is possible for the metal to react increasingly with the amalgam matrix.(25) In the present study, the samples of two groups were also kept in a humid and indoor environment which, given the above discussion, is in accordance with the higher shear strength of amalgam post samples.

Lo et al.(8) who investigated the shear strength of amalgam cores with and without the support of posts and concluded that the use of prefabricated posts increased the shear strength of bond in amalgam cores by three to five times . In another study, Cohen et al. measured and compared the fracture strength of three core restoration materials with and without the support of a Split-Shank prefabricated post and observed an increased fracture resistance in the case of Tytin amalgam with prefabricated post; however, this increase was not statistically significant (20). In the mentioned study, the prefabricated posts increased shear strength resistance. Moreover, in a similar study conducted by Kahn FH et al.,(25) the control group without post demonstrated a lower failure threshold, as compared to the Flexi-Post group. The results of the mentioned study also showed that the mean fracture resistance was higher in the amalgam post group (37.7 kgf), as compared to the group without posts (16.8 kgf).

Finally, some factors, such as the test apparatus, the research method, and the type of material, lead to inconsistency among different researchers, making it difficult to precisely compare the performed methods.

Conclusion

The statistical analysis of the results illustrated a significant difference between the two groups. The use of amalgam for core restoration of root canal-treated teeth along with intra-canal dowel has higher fracture strength, as compared to the nonuse of dowel.

Conflicts of interest

The authors declare that they have no conflict of interest regarding the publication of the current article.

Suggestions for further research

To achieve comparable results, it is recommended that researchers follow a standardized research method to make a more reasonable evaluation of the samples. Furthermore, it is suggested to perform a similar study

Using the crown to investigate the Ferrule effect of the crown on the fracture resistance of the samples.

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