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Evaluation of Different Post and Core Systems for Restoring Pulpectomized Primary Incisors: An In-Vitro Study

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Aim: This in-vitro study was conducted to assess the fracture resistance (FR) of different post and core systems for restoring pulpectomized primary incisors.

Materials and methods: Forty extracted primary incisors were collected, prepared, and then obturated using Metapex. Teeth were allocated into four groups. Group (A): teeth restored with human dentin posts; Group (B): bovine dentin posts; Group (C): glass fiber posts; and Group (D): orthodontic stainless-steel wire in omega-form posts. Dentin blocks were obtained from the roots of extracted human maxillary premolars and bovine permanent incisors to fabricate the dentin posts. These blocks were formed into post shapes using a Computer Numerical Control (CNC) machine. The posts underwent cementation using glass ionomer cement, followed by coronal buildup with composite. After thermocycling, the FR and mode of failure were examined. The FR was analyzed using the Kruskal-Wallis test, while the mode of failure was analyzed using the Monte Carlo test. P-values ≤ 0.05 were used to determine statistical significance.

Results: The median maximum compressive load in group (A) was 386.87 N, in group (B) it was 379.27 N, in group (C) it was 522.16 N, and in group (D) it was 469.14 N. The differences between the groups were not statistically significant regarding the maximum compressive load and the failure mode.

Conclusion: Glass fiber posts and omega posts had higher FR compared to dentin posts, although the four groups can be used effectively for restoring pulpectomized primary incisors.

Keywords: dentin post; bovine post; glass fiber posts; omega posts; fracture resistance.

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Introduction

Children frequently experience crown damage to their primary anterior teeth as a result of trauma or Early Childhood Caries (ECC).[1] Early primary incisors loss will lead to improper habit formation, reduced masticatory efficiency, and speech impairments due to altered pronunciation of specific letters. Additionally, the compromised aesthetics that follow may lead to serious psychological issues.[2]

Reconstruction of mutilated primary incisors is extremely challenging because of the small crowns, extensive pulp chambers, and usually too little intact tooth structure is still present, which increases the likelihood of fractures of the restorations.[3] Pulpectomy followed by post-and-core restoration is what the dentist must do for teeth like these, where the crown is damaged but the root is still intact.[4] The post is used to provide support, stability, and resistance to masticatory stresses to the restored crown.[5]

Unlike the posts used in permanent teeth, the use of short posts is ideal for primary teeth because of the natural resorption that takes place. If the post is inserted 3–4 mm into the root canal, both the eruption of permanent teeth and the resorption of the primary teeth will not be affected.[6]

Posts used for the restoration of primary anterior teeth are biological posts, metal posts, polyethylene fiber posts, stainless steel orthodontic wire, and glass fiber posts.[7] In 1991, Santos and Bianchi invented the term “biological restoration”. Ramires-Romito et al (2000) collected extracted teeth and used them as a post and core.[8]

It has been discovered that the teeth of humans and some animals are comparable to each other. When comparing teeth from cows and humans, the composition of the dentin and enamel is quite similar. Additionally, the benefits of bovine teeth include their bigger size, ease of finding them in sound forms, and increased availability.[9,10]

The dental glass fiber posts are made up of glass fibers inserted uni-directionally into a resin matrix. Their benefits include stress distribution across a large surface area and raising the load threshold.[11] They come in a variety of forms, including parallel, double-tapered, conical, cylindrical, and tapered-shaped.[12]

Mortada and King invented a technique that uses stainless steel wire as a post for primary teeth. Orthodontic stainless-steel wire with a thickness of 22 gauge/0.7 mm was used to create the post. First, an “omega post” design was presented in which the two free ends of the wire were inserted inside the root canal while the loop remained outside the canal to support the coronal restoration. Later, half-omega, alpha, gamma, and modified anchor-shaped post designs were produced.[6]

Ideally, the post should adhere well to the root dentin and have physical characteristics comparable to dentin. But because dentin has such a complicated structure, it is extremely difficult for any synthetic material to replicate every biomechanical characteristic of dentin.[13] So far, no material has been discovered that perfectly mimics the biomechanical characteristics of natural tooth structure. However, there is a lack of evidence in the literature on the utilization of human and bovine dentin posts for restoring primary teeth.

Materials and Methods

This in-vitro study assessed the FR of different post and core systems for restoring pulpectomized primary incisors with the following material combinations: Human dentin post & composite core, bovine dentine post & composite core, glass fiber post & composite core, and stainless-steel post & composite core.

Prior to project processing, protocol acceptance by the Mansoura University Institutional Ethical Committee was obtained (code AM08060922PP). Forty primary incisors were collected from the out-patient clinic of the Pediatric Dentistry and Dental Public Health Department, Faculty of Dentistry, Mansoura University. The teeth were extracted because they were over-retained or clinically non-restorable. The teeth were included if they had been extracted with about half of the roots, and there was no history of pulp treatment.

Sample size was calculated based on the mean FR of post and core retrieved from a previous study.[14] The G* Power program version 3.1.9.7 was used to calculate sample size based on an effect size of 0.82, using a 2-tailed test with α error =0.05 and power = 90.0%, the sample size was at least 10 samples in each group.

All teeth were first cleaned according to the guidelines of the Centers for Disease Control and Prevention (CDC).[15] After that, teeth were autoclaved and stored in a container filled with 0.1% thymol solution. The teeth were decoronated 1mm coronal to the cemento-enamel junction. Preparation of the canals was performed using endodontic Hedstrom files (MANI, Japan), and the canals underwent irrigation using 2% sodium hypochlorite in a side-vented needle (Fanta, China) attached to a 5 ml syringe.

Measurement of the working length was performed visually using Hedstrom file number 15. The file was inserted in the canal until it was visible at the apical foramen, then 1mm was subtracted from this length to confirm the working length. The canals were prepared up to number 40 Hedstrom file. After the mechanical preparation and irrigation, canals were dried using paper points. After that, obturation was performed using calcium hydroxide with iodoform paste (Metapex Plus, Meta Biomed, Korea).[4]

Each tooth was embedded in a self-cure acrylic resin block (Acrostone Dental Manufacture, Egypt) up to 1mm below CEJ, and then every sample received a code including the group and the number of samples. The post space was prepared using the green color-coded drill, which corresponds to a size of 1.5mm (FiberKleer 4X, Pentron, USA). A stopper was attached to the drill to ensure that 3mm of canal was prepared to receive the post.

Teeth were randomly allocated into four groups (N = 10/group). Group (A): teeth restored with human dentin post & composite core; Group (B): bovine dentin post & composite core; Group (C): glass fiber posts & composite core; and Group (D): orthodontic stainless-steel wire in omega-form & composite core.

The lottery simple random sampling technique was utilized. All samples were numbered from 1 to 40, and the numbers were written on identical cards. The cards were put into a container and then shuffled. The cards were taken one by one, and the sample that corresponded to the number on the chosen card was placed in the first group. The procedure was repeated until each group contained 10 samples.

Five permanent maxillary premolars extracted for orthodontic reasons were collected from the outpatient clinic of the Oral & Maxillofacial Surgery, Faculty of Dentistry, Mansoura University, for the fabrication of the human dentin posts. The selected teeth were freshly extracted maxillary premolars with no root caries or previous root canal treatment. The teeth were cut vertically into two halves, so one post was fabricated from each half. Dentin blocks were obtained from the roots, and then these blocks were formed into a post shape using a Computer Numerical Control (CNC) machine (Simo MVC vertical machine, Taiwan). Each post was 6mm in length and 1.5mm in diameter (Figure 1). Autoclaving of posts was performed at 121 °C for 20 minutes.

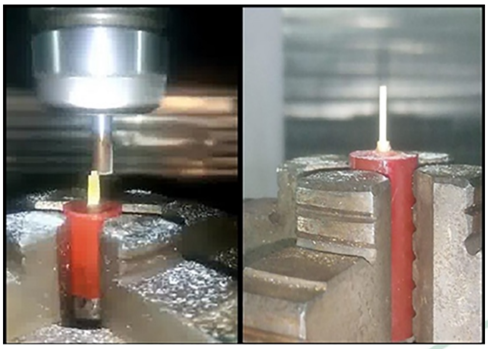

Figure (1): fabrication of dentin post.

Three bovine permanent incisors were extracted from freshly slaughtered bovine in the abattoir for the fabrication of bovine dentin posts. The teeth were cut vertically into two halves, then each halve was sectioned in a vertical direction into two portions; thus, four biological posts were obtained from each incisor tooth. Dentin blocks were obtained from the root, and the posts were fabricated using the same technique as that used to fabricate the human dentin posts. Autoclaving of posts was performed at 121 °C for 20 minutes.

The green color-coded FiberKleer 4X (Pentron, USA) size 1.5mm fiber posts with their corresponding drill were used in this study. The posts were cut to a length of 6mm with a diamond bur using a high-speed handpiece. The stainless-steel posts were fabricated using a piece of orthodontic wire (Leowire, New Zealand) 0.7mm in diameter that was cut and bent to make an omega loop using an orthodontic omega former plier (3M UnitekTM, USA).

In all groups, posts with a length of 6 mm were used, in which 3mm of post was inserted in the canal space, leaving the remaining 3mm outside the canal for coronal buildup. Following adequate adaptation of posts, they were cemented in the canals using glass ionomer cement (GC Gold Label, Japan).

The coronal enamel and dentin were etched for 20 sec using 37% phosphoric acid (Ivoclar Vivadent, Liechtenstein), rinsed, dried, and bonding agent (3M ESPE Single Bond Universal Adhesive, Germany) was applied and cured for 20 seconds. The coronal part of the posts was covered with composite (3M ESPE FiltekTM Z350 XT, A1 Body Shade, USA) for core build-up and light-cured for 20 sec, then composite was applied for crown reconstruction using celluloid strip crowns (Deciduous transparent crowns, TOR VM, Russia).

To replicate temperature changes in the mouth and to increase the accuracy of the results, all the specimens underwent 500 cycles of thermocycling (SD Metachronic thermocycler, Germany). Each cycle involved immersing the samples for 30 seconds in hot water at 55 ± 1 °C and then for the same amount of time in cold water at 5 ± 1 °C. The hot and cold baths were separated by 5 seconds.[16]

The fracture resistance was examined by placing the samples in a specialized fixture and subjecting them to a load that increased gradually at a crosshead speed of 0.5 mm/minute at 148° along the long axis of the primary incisors on the mid-palatal surface using a universal testing machine (Instron 3345 universal tasting machine) until a fracture occurred (Figure 2). The highest force at which the tooth fracture occurs was measured in Newton.[17]

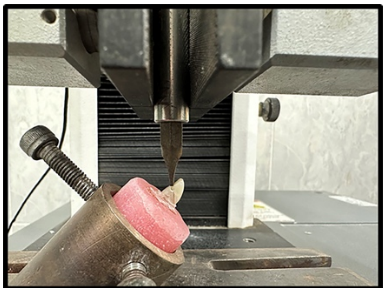

Figure (2): fracture resistance test.

The fracture was analyzed using a 25x magnification stereomicroscope (Nikon SMZ745T Stereomicroscope, Nikon, Japan).

Fractures were considered favorable if they occurred above CEJ and were restorable (Figure 3). Non-favorable fractures are defined as fractures below CEJ that are not repairable (Figure 4).[16]

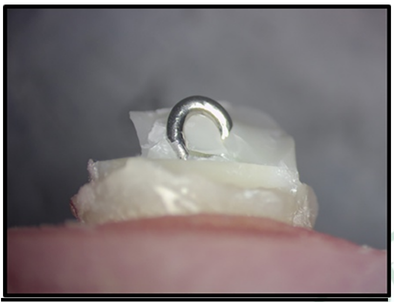

Figure (3): favorable fracture.

Figure (4): unfavorable fracture.

Statistical analysis

Data were analysed by the Statistical Package of Social Science (SPSS) program for Windows V26. The normality of the data was first tested using the Shapiro test. The threshold of significance (p-value) is fixed at the 5% level. A result was considered significant at $p \leq 0.05$.

For the fracture resistance test, continuous variables were expressed as medians (min-max) for non-parametric data. The four groups were compared using the Kruskal-Wallis test, while the two groups were compared using the Mann-Whitney test.

For the mode of failure, qualitative data were expressed as numbers and percents. The correlation between categorical variables was tested with the Monte Carlo test when the expected cell count was < 5.

Results

The results showed the median maximum compressive load in group (A) was 386.87 N, in group (B) it was 379.27 N, in group (C) it was 522.16 N, and in group (D) it was 469.14 N. The difference was not significant (p = 0.293). Although not statistically significant, group (C) had the highest compressive load, followed by group (D), then group (A), and the lowest load was in group (B) (Table 1).

Table 1: Maximum compressive load (N) among the studied groups:

Groups	no	Maximum Compressive load (N)			Test of significance P value
		Mean ± SD	Median	Min-Max	
Group (A)	10	350.94±187.41	386.87	50.10-595.26	KW=3.72 p=0.293
Group (B)	10	412.49±157.51	379.27	216.65-704.45	
Group (C)	10	689.19±534.22	522.16	191.43-1876.32	
Group (D)	10	470.77±211.59	469.14	155.50-762.11	

KW: Kruskil wallis test, P value >0.05 not significant

The results also revealed that groups B and D have the highest percentage of favorable fractures (70.0%), followed by group A (50.0%). Conversely, group C has the lowest percentage of favorable fractures (40.0%). However, the calculated P value (0.526) suggests that these observed differences in favorable outcomes among the groups are not significant (Table 2).

Table 2: Distribution of the favorable and unfavorable fractures among the studied groups:

Outcome	Group (A) (n=10)	Group (B) (n=10)	Group (C) (n=10)	Group (D) (n=10)	P value
Favorable	5 (50.0%)	7 (70.0%)	4 (40.0%)	7 (70.0%)	0.526
unfavorable	5 (50.0%)	3 (30.0%)	6 (60.0%)	3 (30.0%)	

Monte carlo test was used, P value >0.05 not significant

Discussion

In the current study, forty extracted primary incisors were utilized, this agrees with Barghi and Sharifi[18] who examined primary incisors in their investigation. Compared to primary molars, the primary incisors have bigger roots, more susceptible to trauma and ECC, their canals are easier to prepare, and additionally, it is more difficult to find extracted primary molars with intact roots. On the other hand, Ghazawy and

Badran[17] and El-Shaabany et al[14] used extracted primary incisors and canines in their investigations.

All teeth were cleaned following the CDC recommendations[15]. Then teeth were autoclaved and restored in a container filled with 0.1% thymol solution; this is consistent with Jarahi et al[19], who found that when restoring teeth for more than six months, the combination of autoclaving and thymol was considered the best method of sterilization. In this study, storage duration ranged from two weeks to nine months. This broad range in storage duration was due to the difficulty of collecting extracted incisors with specific criteria.

The crowns were cut horizontally, 1mm coronal to the cementoenamel junction, to mimic a clinical situation where the tooth structure was severely damaged. Therefore, the post and core will carry the majority of the compressive load applied to the tooth. This is in agreement with several authors who used the same concept.[14,17,20,21]

Pulpectomy was performed using calcium hydroxide with iodoform paste (Metapex) because it is simple to apply, radiopaque, resorbs at a slightly quicker rate than the natural resorption of primary roots, and has no harmful impact on the permanent successors. These factors make Metapex a material that is widely used for primary tooth root fillings.[21,22,23,24]

Several authors used post's drill to prepare the post space.[14,18,21] In our study, the space for the post was created using a post's drill of 1.5 mm diameter, in which a stopper was attached to the drill to ensure that 3 mm of the canal was prepared to receive the post. In contrast, Ghazawy and Badran[17] used a plugger with a rubber stopper to condensate the obturation material, leaving the coronal space to receive the post. Additionally, some studies used round and fissure burs to create the post space.[25,26]

According to Shah et al[6], the use of short posts is ideal for primary teeth because of the natural resorption that takes place. If the post is inserted 3–4 mm into the root canal, both the eruption of permanent teeth and the resorption of the primary teeth will not be affected. In the current study, we used posts of 6 mm in length, of which 3mm were inserted inside the canal, leaving the remaining 3mm for coronal buildup.

Maxillary premolars were utilized in the current investigation to fabricate the human dentin posts since they are the most frequently extracted teeth for orthodontic purposes, so they are commonly found in good condition. Dentin blocks were obtained from the roots, and then these blocks were formed into a post shape using a Computer Numerical Control (CNC) machine. This is in agreement with Ghazawy and Badran[17] and El-Shaabany et al[14], who used the same concept, while Hijazi et al[21] used Computer-Aided-Design Computer-Aided-Manufacturing for fabrication of the dentin posts.

Tavano et al[27] used bovine incisors to fabricate dentin posts. The same concept is used in this study. The bovine posts were fabricated using the same technique as that used to fabricate the human biological posts. According to Soares et al[9] and Penelas et al[10], the composition of human teeth and bovine teeth is quite similar. Additionally, bovine teeth have many advantages over human teeth, such as being easier to find in large quantities, staying in better condition, being generally wide and smooth, and having no caries or other defects that could affect their quality.

Cementation of the posts was performed with GIC. Many advantages are provided by the GIC, such as fluoride release, cariostatic potential, easy mixing, acceptable flow properties, reasonable cost, adhesion to base metals and tooth structure.[28] Several studies did not demonstrate statistically significant differences in fracture resistance and push-out bond strength of posts cemented using GIC and self-adhesive resin cement.[29,30,31] In the current study, to replicate temperature changes in the oral cavity and to increase the accuracy of the results, all the specimens underwent 500 cycles of thermocycling. This is in agreement with Seraj et al[16], who used the same concept.

An important and desirable property of restorative materials is their ability to resist fractures. In our study, the samples were placed in a specialized fixture and subjected to a load that increased gradually at a crosshead speed of 0.5 mm/minute at 148° along the long axis of the primary incisors on the mid-palatal surface using a Universal Testing Machine until the tooth fractured. The highest force at which fracture occurred was measured in Newton. This is in agreement with several studies.[23,24,25,26] On the other hand, some studies[17,21] assessed the fracture resistance using a 45° inclination angle, while other authors[14,18] used an angle of 135°.

According to Jindal et al[32], in order to mimic the occlusal forces that occur on primary incisors in class one occlusion, the 148° should be used instead of 135°, which will be ideal for permanent incisors in class one occlusion. It is important to keep in mind that chewing forces are multi-directional and very complicated, while in the fracture resistance test the forces were applied to only one direction, and this is considered a major limitation of in-vitro studies.

In the study by Mountain et al[33], the maximum bite force on primary anterior teeth in three- to six-year-old children ranged from 6.87 N to 140.09 N (mean = 49.58 N). In the current study, the mean maximum compressive load in group (A) was 350.94 N (median = 386.87 N), group (B) was 412.49 N (median = 379.27 N), group (C) was 689.19 N (median = 522.16 N), and group (D) was 470.77 N (median = 469.14 N). There were no significant differences between the groups. Since the mean FR in all the groups was higher than the maximum bite force, all groups are considered clinically acceptable.

In our study, the glass fiber post group exhibited a greater compressive fracture resistance load than the human dentin post group; however, there were no significant differences between the groups. Conversely, El-Shaabany et al[14] and Hijazi et al[21] found that teeth restored with dentin posts had a significantly higher FR compared to teeth restored with glass fiber posts. While Ghazawy and Badran[17] found the glass fiber posts had a significantly higher FR compared to biological dentin posts, these differences may be due to the use of different agents for cementation of the posts and the use of different angles in the fracture resistance test.

In agreement with the study by Nilavarsan et al[20], the glass fiber post group in this study exhibited a greater FR than the omega-shaped post group; however, the differences between the groups were not significant. In contrast, Gab and co-workers[34] showed that glass fiber posts had statistically significantly greater FR means than omega-shaped posts. This might be due to the differences in storage solutions, obturating materials, and cementation techniques that were used.

When comparing the human dentin posts, bovine dentin posts, and glass fiber posts, the results revealed that the glass fiber posts exhibited a higher FR than the dentin groups, but the differences between the groups were not significant. This is in agreement with Tavano et al[27] who evaluated the FR of human permanent canines restored with bovine dentin posts, human dentin posts, or glass fiber posts and found that the glass fiber posts had higher FR than the dentin posts, but the differences were not significant.

In our study, the fracture was analyzed using a 25x magnification stereomicroscope. The results revealed that there were no significant differences in fracture patterns between the groups. This is in agreement with several studies.[16,18,24,25] One possible explanation for this might be that, due to the difficulty of collecting extracted teeth using particular criteria, the sample size utilized in this study was the smallest calculated sample size, and a greater sample size could lead to different outcomes.

Limitations

The limitations of this study were that the dehydration of teeth during the study differs from the clinical situation where the teeth are always hydrated, and there was a lack of studies that evaluated the use of bovine dentin posts for restoring primary teeth, which made it difficult to compare the findings with those of other research. Another limitation was that it is difficult to simulate the chewing forces, which are multi-directional and very complicated, while in the fracture resistance test, the forces were applied in only one direction.

Conclusion

Within the limitations of this study, it can be concluded that the glass fiber posts and omega-posts had higher FR than the human and bovine dentin posts, although all groups exhibited fracture resistance greater than the maximum bite force in children, indicating that they can be successfully utilized to restore severely damaged primary incisors.

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