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Dissertação de Mestrado

Título:

Tooth fragment reattachment: evaluation of fracture resistance using intermediate materials *versus* direct composite restoration.

Autor:

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Colagem do fragmento dental: avaliação da resistência a fratura usando materiais intermediários *versus* restauração em resina composta direta.

Dissertação apresentada ao Programa de Pós-Graduação em Odontologia da Faculdade de Ciências da Saúde da Universidade de Brasília, como requisito parcial à obtenção do título de Mestre em Odontologia.

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A meus pais, Júlio e Sônia.

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“Porque te hago saber, Sancho, que la boca sin muelas es como molino sin piedra, y en mucho más se ha de estimar un diente que un diamante.”

Don Quijote de la Mancha, Miguel de Cervantes, 1605

ABSTRACT

Introduction: Tooth fragment reattachment technique has demonstrated high success rates, being a low-cost, conservative treatment option with good functional and aesthetic recovery. Several studies have evaluated the influence of composite materials used in this technique, however, there are still no studies evaluating the use of preheated composite resin in the reattachment technique. **Aims:** evaluating the influence of different intermediate material on the fracture resistance of the teeth that were subjected to reattachment technique, as well as this restorative technique with that of direct composite resin restoration. The tested null hypothesis was that there was no statistically significant difference between the groups, regardless of the restorative technique used. **Materials and methods:** 120 bovine teeth were randomly divided into groups (n = 15). After fracture simulation of the teeth, each sample was assigned to one of the following groups: G0 - negative control, sound teeth; G1 - bonding with conventional composite resin Z100; G2 - bonding with pre-heated composite resin Z100; G3 - bonding with conventional composite resin Z350; G4 - bonding with pre-heated composite resin Z350; G5 - bonding with flow resin Z350XT flow; G6 - bonding with RelyX Veneer resin cement; G7 - direct Class IV restoration with Filtek ™ Z350 XT Resin. The fracture resistance test was performed on a universal testing machine, under tangential compression on the fragment, at a speed of 1mm / min^{-1}. The data were submitted to one-way ANOVA and the post hoc Tukey test (5%). **Results:** The control group (G0) showed the highest values of fracture resistance, being statistically different to the other experimental groups ($p<0.05$), except for the groups whose fragment was bonded using pre-heated resin. There was a statistically significant difference between groups G1 to G6 (one-way ANOVA, $p=0.04$). It was observed that G2 (bonding with pre-heated composite resin Z100) and G4 (bonding with pre-heated composite resin Z350) presented the highest values of fracture resistance. For resin Z100, there was a significant difference between bonding with or without preheating (G1 and G2; $p<0.05$); while for resin Z350 (G3 AND G4) this difference was not observed ($p>0.05$). When heated, G2 and G4 showed significantly higher fracture resistance values compared to the flowable resin (G5) ($p<0.05$), being similar to the sound teeth group (G0). However, when compared to RelyX Veneer resin cement, only the heated Z100 resin was statistically different ($p<0.05$). There was no statistically significant difference between the reattached or directly restored groups (t-test, p = 0.53). **Conclusion:** The tooth reattachment technique using pre-heated composite resin showed the highest values of fracture resistance, being similar to the sound teeth group. There was no difference between the fragment reattachment technique compared to direct composite technique.

Keywords: fragment bonding, dental trauma, coronary fracture.

RESUMO

Introdução: A restauração de dentes com a colagem do próprio fragmento dental tem demonstrado altas taxas de sucesso, sendo uma opção de tratamento de baixo custo, conservadora e com boa recuperação funcional e estética. Diversos estudos avaliaram a influência dos materiais intermediários resinosos utilizados na técnica, porém, ainda não existem estudos avaliando o uso da resina composta pré-aquecida na técnica de colagem. **Objetivo:** comparar a influência do tipo de material intermediário na resistência à fratura dos dentes que foram submetidos à colagem, bem como comparar a técnica da colagem com a da restauração em resina composta direta. A hipótese nula testada é a de que não há diferença estatisticamente significante entre os grupos, independente da técnica de colagem utilizada. **Materiais e métodos:** 120 dentes bovinos foram utilizados e aleatoriamente divididos em grupos (n = 15). Após a fratura dos dentes, cada amostra foi atribuída a um dos seguintes grupos: G0 - controle negativo, hígidos; G1 - colagem com resina composta convencional Z100; G2 - colagem com resina composta pré-aquecida Z100; G3 - colagem com resina composta convencional Z350; G4 - colagem com resina composta pré-aquecida Z350; G5 - colagem com resina flow Z350XT *flow*; G6 - colagem com cimento resinoso RelyX Veneer; G7 - restauração classe IV direta com Resina Filtek™ Z350 XT. O teste de resistência à fratura foi realizado em uma máquina de ensaios universal, sob compressão tangencial no fragmento, a uma velocidade de 1mm/min-^{1}. **Resultados**: O grupo controle (G0) apresentou valores de resistência a fratura estatisticamente superiores aos demais grupos experimentais ($p<0,05$), com exceção dos grupos cujo fragmento foi colado com resina aquecida. Foi observada uma diferença estatisticamente significativa entre os grupos G1 a G6 (ANOVA *one-way*, $p=0.04$). Observou-se que G2 (Colagem com resina composta pré-aquecida Z100) e G4 (Colagem com resina composta pré-aquecida Z350) apresentaram os maiores valores de resistência à fratura. Para a resina Z100, houve diferença significativa entre colagem com ou sem aquecimento (G1 e G2; $p<0,05$); enquanto para resina Z350 (G3 E G4) essa diferença não foi observada ($p<0.05$). As duas resinas quando aquecidas (G2 e G4) apresentaram valores significativamente maiores de resistência à fratura do que a resina *flow* (G5) ($p<0.05$). No entanto quando comparados ao cimento resinoso RelyX Veneer, somente a resina Z100 aquecida foi estatisticamente diferente ($p<0.05$). Não foi observada diferença estatisticamente significativa entre os grupos colados ou restaurados (t-test, p=0.53). **Conclusão:** Os grupos onde a colagem foi realizada com resina composta pré-aquecida apresentaram os maiores valores de resistência à fratura, sendo semelhantes ao grupo hígido. Não houve diferença entre os grupos colados ou restaurados.

Palavras-chave: colagem de fragmento, trauma dental, fratura coronária.

FIGURES LIST

TABLE LIST

SUMARY

1. INTRODUCTION

Dental trauma has a high prevalence, where one in four people suffers some type of oral injury during childhood and youth, mainly affecting males. (1) Due to their vulnerable position in the arch (2), the incisor teeth are the most affected by impacts, with luxation being the most common type of injury in primary dentition; in permanent dentition, the crown fracture. (3) (4) (5) (6) The extent of the fracture, age of the patient, root development, involvement of pulp and periodontal tissues, complications in terms of aesthetics, and the quantity and quality of remaining dental tissue must support the treatment strategy. (7)

Treatment options for restoring traumatized teeth may be or not be invasive, depending on the severity of the injury. Among them are resin crowns, ceramic crowns, and direct restoration with composites, all of which may or may not need an intraradicular retainer. (3) (7) (8) (9) However, despite being feasible in the total or partial recovery of the mechanical strength of the tooth, these possibilities present a high cost, may require the wear of healthy dental structure, require more clinical time, and are more sensitive to the technique, creating difficulties in obtaining adequate shape, surface texture, and translucency. (3) (10)

Restoring the tooth by simply bonding the dental fragment itself recovers approximately 37-50% of its fracture resistance (11) (12) and has demonstrated high success rates, promoting aesthetic-functional recovery with the use of little restorative material, security, conservatism, simplicity, speed, lower cost, in addition to providing positive emotional and social conditions. As such, it has become increasingly popular. (7) (8) (10) (13) (14)

The procedure is feasible due to the adhesion of dental materials, which depends on the substrate hybridization. (15) (16) (17) (18) (19) (20) The patient should then be instructed to store the tooth fragment in a hydration solution immediately after the trauma to avoid discoloration and dryness of the dentine, since hydrophilic adhesives require adequate hydration of dentin for better adhesion, and maintaining hydration positively influences bond strength (BS). (3) (10) (21) (14) (22) (23) (24) (25)

However, when adhesives are associated with composite resin, fracture resistance might be improved (26), because it will fill in the possible gaps in the tooth/fragment interface. (11) The choice of intermediate material used in the tooth fragment reattachment may vary, ranging from conventional composite resin to flowable resin, resin cement, glass ionomer cement and, more recently, the composite resin previously submitted to heat has been gaining space for the realization of cementations. (27) According to Reis et al (28), the combination of materials used is as important as the prior preparation of the substrate regarding fracture resistance.

For this reason, the present study evaluated the fracture resistance of teeth restored by the tooth fracture reattachment technique using different intermediate materials, as well as comparing this technique to the direct composite resin (class IV restoration), through an *in vitro* study.

2. LITERATURE REVIEW

2.1 DENTAL TRAUMA

Among the trauma incidence, those that comprise the oral region represent about 5% of all injuries, and range from bone fractures, damage to soft and hard tissues, lesions of the face and, mainly, teeth - being classified as dental trauma (DT). Although these injuries are more common in certain groups, no individual is ever at zero risk through their activities of daily living - it is usually sudden, circumstantial, unexpected, accidental, and often requires emergency attention. DT is not a disease, but a consequence of several unavoidable risk factors in life, being a public health problem, resulting from its high prevalence, which ranges from 7.4%-58%. (3) (4) (26) (29) (30) (31) (32) Some people are not affected by dental trauma through whole lifetime while some of them experience them repeatedly and even on the same tooth. (33)

Existing data on prevalence of traumatic dental injuries varies between countries, and the differences of design of performed studies could be one of the explanations of such variety of the results. (34)

Direct or indirect impact may result in DT. The extent of the damage is related to such factors as energy of impact, resilience and shape of the impacting object, direction of the impact and the reaction of the tooth surrounding tissues.

The type and causes of DT depend on the type of dentition involved (permanent or primary dentition). (35) (36) This phenomenon might be related to the features of the underlying bone structure which in primary dentition is less mineralized than in permanent. Therefore, trauma in primary dentition more often results in displacement of the tooth. Among adult individuals, coronary fractures are the most common injury, being enamel and dentin fractures without pulp involvement the most frequently diagnosed condition. (29) (37) (38) (19) (39) (40) (31) In primary dentition there was a greater range of trauma associated with falls and collisions due to the increase of independent movements in age group between 0-6 years, while accidents during playing, sport injuries increased in age group between 7-15 years and violence resulted in dental injuries most frequently in age group 21-25 years (41) (42)

DT mainly involve front teeth of the upper jaw and predisposing factors could be related to the person’s anatomic features: increased overjet, inadequate lip coverage of the upper anterior teeth etc. (43) (44) Noori and Al-Obaidi (45) observed that children with class II division 1 malocclusion were more often reported (70%) to have traumatic dental injuries than children with other types of occlusion. Children with an overjet with size greater than 3.0 mm were 5.4 times more likely to present a dental injury than children with an overjet size equal to or lower than 3.0 mm. Schoolchildren with inadequate lip coverage presents a fourfold higher risk of traumatic dental injuries. (46) (47)

Males, in general, experiences traumatic dental injuries at least twice as often as females. Such data could be attributed to greater participation of boys in contact sports, fights, and car accidents. (48) (49) (50) (51) This fact can also be related to cultural differences, as females acquire more mature behaviors at a younger age. Some studies have shown a reduction in the gender ratio, as girls are participating more in sports activities. (44)

2.2 CLASSIFICATION OF TRAUMATIC DENTAL INJURIES

To standardize and facilitate communication between professionals involved in the treatment of lesions to the hard dental tissues and the pulp, there are several classifications for injuries that involve the oral region. To be satisfactory, any classification should be easy to apply and understand and be clinically relevant. Among the existing classifications, we can mention that of Andreasen. Table 1 (52)

Table 1 Classification of injuries to the tooth structure.

Type of injury	Description
Infraction	An incomplete fracture (crack) of the enamel without loss of tooth substance
Enamel fracture	A complete fracture of the enamel / Loss of enamel / No visible sign of exposed dentin
Enamel–dentine fracture (uncomplicated crown fracture)	A fracture with loss of tooth substance confined to enamel and dentine, but not exposing the pulp

Table 1 Classification of injuries to the tooth structure.

Type of injury	Description
Enamel–dentin–pulp fracture (complicated crown fracture)	A fracture involving enamel and dentin with loss of tooth structure and exposure of the pulp
Crown–root fracture	A fracture involving enamel, dentine and cementum, exposing or not exposing the pulp
Root fracture	A fracture involving dentine, cementum and the pulp. Root fractures can be further classified according to displacement of the coronal fragment

2.3 TOOTH FRAGMENT REATTACHMENT AS AN OPTION FOR UNCOMPLICATED CROWN FRACTURE

The restoration of an anterior tooth by reattaching the original fragment seems to be the most conservative treatment approach for uncomplicated crown fracture cases. When compared with other restorative techniques, such as direct composite restorations, laminate veneers, intraradicular retainers, etc., reattaching the fragment itself can offer several advantages including improved esthetics and function, and restoration of the surface anatomy with increased wear resistance. (40) (53) (26)

Figure 1 Fractured crown prior the bonding of the fragment. Image courtesy of Patrícia Ferronato, University of Brasilia (UnB), Brazil.

Figure 2 Teeth restoration using the tooth fragment reattachment technique. Image courtesy of Patrícia Ferronato, University of Brasilia (UnB), Brazil.

Many previous attempts towards improving the fracture strength of the reattached fragment have been made. Scientists have tested several retentive preparation designs, as well as different composites and adhesive materials for the reattachment of tooth fragments. (26) (11) (28) (10) (54) (55) (56) (57) (58) (59) With the advances in the field of adhesive dentistry, some researchers have attempted to reattach fragments using these materials without an additional retentive preparation. Bhargava (59), Bruschi-Alonso (10), Coelho-de-Sousa (57), Pusman (26) and Chazine (58) reported that additional preparation of the fragment or tooth shows a better performance for resistance to fracture.

Such preparation methods include enamel beveling of the fragment and remaining crown, internal dentin groove, external chamfer, and the overcontour technique. In light of many published studies that verified the efficacy of the fragment reattachment techniques, it has become apparent that both the preparation technique and the kind of material used to bond fractured fragments may have significant effects on the fracture strength of such restored teeth. (54) (55) According to Garcia (60) and De Sousa (61), the simple tooth fragment reattachment is the preferred reattachment technique and there is an increase in the BS between tooth fragment and dentin when an intermediate material is used.

A fundamental aspect of the best prognosis for attachment of the fragment to the remaining tooth is fragment hydration, which promotes greater BS than with dehydrated fragments. (3) (10) (14) (21) (24) Maia (25) claims that the solution used to hydrate the fragment, as well as the immersion time, does not interfere with fracture strength after fragment bonding. A 1 hour hydration time in any media (tap water, saline, milk, artificial saliva or coconut water) was sufficient to assure similar bond strength values of the fragment to the remaining tooth structure compared with 24 hours hydration using a multimodal adhesive system associated with a flowable resin composite, reinforcing the importance of hydration for the viability and success of the technique.

2.4 DENTAL ADHESION AND COMPOSITES

One of the most significant aspects of dental materials advancement in the past 50 years is the development of adhesives for dental applications. This has greatly increased the options open to the restorative dentistry, and bonding the fragment to its reminiscent is only possible due to dental adhesion.

The bond with dental substrates is based on an exchange process in which minerals removed from the dental hard tissues after acid conditioning are replaced by resin monomers that become micromechanically interlocked in the porosities upon polymerization. (62) (63) Providing an equally effective bond to enamel and dentin is a main challenge for current adhesives. (64) Acid-etched enamel sets resin tags within the surface, effectively sealing the restoration margins in the long-term. (63) (65) On the other hand, bonding to dentin is less predictable due to the presence of significant amount of water and organic material in the substrate. (62) (66) (67) Besides, regarding adhesion to dentin, the “smear Layer” (a uniform layer of debris made of hydroxyapatite and altered collagen that plugs the entrance of dentinal tubules reducing its permeability) makes another challenge. (23) (68)

Currently, adhesion strategies are grouped into two basic categories: Etch-and-rinse (ER) strategy and self-etch (SE) strategy. ER strategy involves complete removal of the smear layer and superficial hydroxyapatite through etching with an acid gel followed by infiltration of adhesive monomers that permeate the micro-porosities forming hybrid tissue known as the “hybrid Layer”. (23) (63) In contrast, the SE strategy does not require a separate phosphoric acid-etch step as acidic adhesive monomers are utilized to partially dissolve the smear layer and demineralize the underlying dentin/enamel while infiltration is achieved simultaneously. (63)

The newest adhesive systems are “Universal” or “Multi-mode” adhesives which provide dentists with the choice of selecting the adhesion strategy – ER, SE, or an alternative "selective enamel etching" (SEE) strategy, which is a combination of ER strategy on enamel and SE strategy on dentin. (69) (70) (71) (72)

Teeth restored with the dental fragment reattachment technique have higher fracture resistance values when bonding is performed concurrently with a composite and not with the adhesive only, since the composite provides better remnant-fragment adaptation, filling possible gaps. (26) (28) (56) (57) This increased performance depends on the composition of the resin, as the monomeric matrix and the filler particles of each material influence the mechanical properties, biocompatibility, and aesthetic quality. (73)

A composite material is one that is composed of more than one different constituent. (74) There are many composite materials in use in dentistry, and its range includes composite resins, flowable composite resins, resin cements, among others. These materials are composed of a chemically active resin component and a filler, usually a glass or ceramic. The resin and the filler are bound together by a silane coupler. The structure of a resin composite is illustrated in Figure 3, and the constituents of resin composite materials are shown in Table 2. (74)

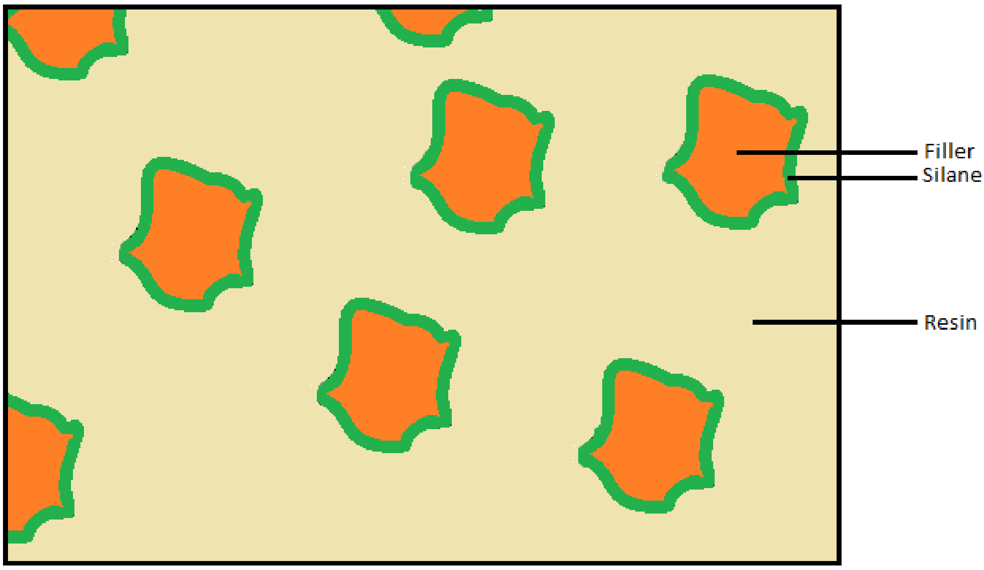

Figure 3 Composition of a resin-based composite material.

Table 2 Chemical constituents of resin composite materials and its reason for use.

Ingredient	Examples	Function
Filler (inorganic)	Glass	Provides strength
	Ceramic	Influences the optical properties of the material
Principal monomer	Bis-GMA	Forms polymer matrix
	Bis-EMA	Used as a primary monomer
	UDMA	
Diluent monomer	TEGDMA	Reduces the viscosity of the main resin so that the material can be used clinically
	UDMA	
Silane coupling agent	γ-methacryloxypropyltrimethoxysilane	Bonds the filler to the resin
Photo-initiators	Camphorquinone	Initiator of polymerization reaction
	PPD	
	Lucirin TPO	
Other chemicals for the curing process	Tertiary amine such as N,N-dimethyl-ptoluidene	Accelerator of polymerization reaction
Ultraviolet stabilizers	2-hydroxy-4-methoxybenzophenone	Prevents shade change over time due to oxidation
Polymerization inhibitors	Monomethyl ether of hydroquinone	Prevents premature curing of the composite prior to use
Radiopaque materials	Barium, strontium and lithium salts	Permits the material to be seen on radiographs
Pigments and opacifiers	Iron and titanium oxides	Varies the optical properties and the colour of the final material to achieve a good shade match

The main resin component is based on the chemical reaction of bisphenol A and glycidyl methacrylate, forming a chemical called bis-GMA (bisphenol A diglycidyl ether dimethacrylate). It is a long chain monomer with a methacrylate group at either end of an aromatic ring. This chemical is highly viscous due to its high molecular weight and aromatic ring, which reduces the mobility of the monomer. Therefore, other monomers are added to the bis-GMA, to permit clinical handling and proper mixing with the inorganic components.

These lower-molecular-weight monomers are called diluent monomers. Examples of these chemicals are MMA, EGDM, TEGDMA, and UDMA. Chemicals such as methyl methacrylate have low molecular weights and have only one reactive group. This leads to greater shrinkage. Single methacrylate group materials produce poor wear resistance, poor strength, and shrinkage is marked on polymerization. The dimethacrylates have active methacrylate groups at either end of a backbone. The longer the backbone, the smaller the shrinkage as the reaction only occurs at the active methacrylate groups. Bis-GMA is an example of this, having a long backbone made up of phenolic aromatic rings. UDMA also has a long chain backbone, but in this case, it does not contain phenolic groups with the backbone being made up of aliphatic components. UDMA is now used quite frequently as an alternative to bisGMA.

Inadequate wear, high shrinkage, and increased exothermic reaction are some of the deficiencies of the resin if used alone. The incorporation of an inorganic filler into the system compensates for these shortcomings. The material thus created should exhibit increased strength, increased wear resistance and reduced polymerization shrinkage.

A sort of composite resin widely used today is called flowable resins. The fluidity of a resin is considered a desirable handling property, as it allows the material to be injected through small-gauge dispensers, thus simplifying the placement procedure, and expanding the range of applications. However, there is concern regarding the lower mechanical properties of flowable resins when compared to traditional composites, which discourages their use in restorations that will undergo high stress (class I, for example). Besides, the fluidity that flowable resins exhibit is due to a reduction in the amount of inorganic filler, which leads to greater polymerization shrinkage. (75)

Along with composite resins, another material that has been widely used is resin cements. Resin cements have become popular in clinical use due to their ability to bond with both tooth and restorative materials. The composition of most resin cements is similar to that of composite resins for restoration. However, they differ from them, mainly due to the lower filler content and lower viscosity. (76)

2.5 PRE-HEATED COMPOSITE RESIN

To improve the mechanical properties and facilitate its application, heating the composite resin with portable heating devices has proved to be an interesting study field, as heating the composite reduces its viscosity and facilitates its insertion into the cavities, providing a better marginal adaptation. (77) (78) Heating also improves the conversion of monomers, which increases the physical and mechanical properties of the final restoration. (79) Lucey et al (80) evaluated the effects of preheating restorative resins, and noticed an increase in the hardness of this material, probably due to the greater mobility of monomers during the growth of polymer chains.

Devices like the Hotset (Technolife, Joinville, SC, Brazil) are used to heat the composites to a desired temperature. The composite syringe can be inserted into the device, and the choice of temperature is made by the operator (there are two temperature options).

Therefore, the use of pre-heated resin seems to be a viable option to improve the prognosis of the tooth fragment reattachment technique. However, there is a gap in the literature regarding this possible technique.

Figure 4 Hotset device.

3. OBJECTIVES

3.1 GENERAL

This study aimed to evaluate the effect of different composite materials on the fracture resistance of teeth after the fragment reattachment technique or direct composite resin restoration. Also, another aim is to analyze the fracture patterns.

3.2 SPECIFIC

To test the following null hypotheses:

1- There is no difference between the materials used to reattach the fragment (photoactivated resin cement, conventional and flowable composite resins, or preheated conventional resins) in tooth fracture resistance;

2- There is no difference between using the same material in the conventional or preheated way;

3- There is no difference between the techniques of fragment reattachment and direct composite restoration (class IV) regarding the fracture resistance of the tooth.

4. MATERIALS AND METHODS

4.1 SAMPLE SELECTION AND PREPARATION

Tabela 3 Expiration date, batch numbers and chemical composition of the materials used in this study (3M ESPE).

PRODUCT	EXPIRATION DATE	BATCH NUMBER	CHEMICAL COMPOSITION
Single Bond Universal	17/10/21	1932400375	10-MDP, phosphate monomer, dimethacrylate resins, HEMA, methacrylate-modified polyalkenoic acid copolymer
Filtek Z350 XT A3E	11/04/22	1918400381	Bis-GMA, UDMA, TEGDMA, PEGDMA, Bis-EMA
Filtek Z350 XT A3E	11/04/22	1918400381	
Filtek Z350 XT A3E	11/04/22	1918400381	
Filtek Z350 XT A2B	17/10/22	1932400596	
Filtek Z350 XT A3D	11/07/22	1921800178	
Z100 A3	14/05/22	1916200468	Bis-GMA, TEGDMA
Z100 A3	14/05/22	1916200468	
Filtek Z350XT Flow A3	28/03/2021	NA43750	Bis-GMA, UDMA, TEGDMA, PEGDMA, Bis-EMA
RelyX Venner A3	28/04/21	NA69423	TEGDMA, Bis-GMA

A total of 200 central and lateral bovine incisors were selected from Nellore cattle, aged about 5 years and presenting 250 kg of clean weight, treated according to strict quality standards and under the supervision of the Ministry of Agriculture (SIF 175). According to CONCEA (Ministério da Ciência, Tecnologia e Inovação) no ethics committee approval was required. Curettes and pumice stone in low rotation were used to remove tissue debris.(Figure 5) The teeth were stored in bottles containing 0.1% thymol solution, diluted in distilled water, to inhibit bacterial growth until the experiment was carried out .(Figure 6)

The size of 10% (n = 20) of the collected teeth were randomly measured with a digital caliper. Then, the value of 25,5mm was obtained as the arithmetic mean for the cervico-incisal length and 16.27mm as the mesio-distal width. (Table 4) The cervico-incisal length corresponds to the distance from the cement-enamel junction to the incisal border. The medio-distal width corresponds to the distance between the distal and mesial surfaces of the tooth.(Figure 7)

Table 4 Arithmetic mean of the dimensions of 10% of the collected teeth.

Sample	Cervico-incisal length	Mesio-distal width
1	24,36	15,53
2	27,31	15,28
3	27,38	17,70
4	25,05	17,47
5	24,88	15,12
6	24,52	16,36
7	25,98	14,28
8	25,23	16,02
9	24,74	15,43
10	24,83	19,47
11	23,52	16,34
12	24,83	16,43
13	25,64	15,91
14	25,74	16,36
15	27,44	16,39
16	25,84	16,41
17	25,05	16,12

Table 4 Arithmetic mean of the dimensions of 10% of the collected teeth.

Sample	Cervico-incisal length	Mesio-distal width
18	26,41	15,12
19	26,18	17,89
20	25,22	15,79
Mean (mm)	**25,5**	**16,27**

The teeth were separated according to the crown dimensions (25.5 ± 1mm cervico-incisal length and 16.27 ± 1mm mesio-distal width). Teeth that did not fit the desired dimensions or had structural defects, such as palatal/incisal wear or cavities, were discarded. 129 teeth remained.

Randomly, using Microsoft Excel, 120 of the 129 teeth were selected to this experimental study.

4.2 FRACTURE SIMULATION

To simulate a coronary fracture in a standardized way and to obtain fragments of the same size, a line was drawn 5 mm from the incisal edge, parallel to it, in each selected tooth.(Figure 8) This value was defined based on previous studies, in which bovine teeth with an average cervical-incisal size of 26 mm were sectioned, exposing enamel and dentin, however, without exposing the pulp chamber. (25) (24)

In order to position the teeth properly for cutting, an “L” shaped acrylic resin support was fabricated. The teeth were, one at a time, fixed to this support with low fusion godiva (DFL, Brazil).(Figure 9) Then, the support was attached to the Micromet Evolution precision metallographic cutter (Erios, Brazil).

The specimens were sectioned, in the buccal-lingual direction, in the previously marked line, with a cutting disc (Extec Dia. Wafer Blade 102 mm x 0.3 mm x 12.7 mm, Enfield; CT, USA), at speed 8 (0-10) and always under running water.(Figure 10)

Being sectioned, the remaining teeth were stored in distilled water, simulating the oral cavity. The respective fragments were kept in distilled water for 1 hour, keeping the dentin hydrated and simulating the time that the patient would take to reach the dental office after the trauma occurred. (Figure 11)

The selected teeth (120) were randomized into eight groups (n=15), based on the different restorative protocols as follows: Group 0 (G0) - positive control (sound tooth); Group 1 (G1) - fragment reattachment using Z100 (3M ESPE); Group 2 (G2) - fragment reattachment using Pre-heated Z100 (3M ESPE); Group 3 (G3) - fragment reattachment using Z350 (3M ESPE); Group 4 (G4) - fragment reattachment using Pre-heated Z350 (3M ESPE); Group 5 (G5) - fragment reattachment using Z350XT flow (3M ESPE); Group 6 (G6) - fragment reattachment using RelyX Veneer (3M ESPE); Group 7 (G7) - direct class IV restoration using Filtek™ Z350 XT (3M ESPE). The groups and its restorative protocols are described in Table 5 for easy reading.

Table 5 Description of the material used in each group and the correspondent number of the specimen selected for each group, according to randomization done in Microsoft Excel.

Group	Intervention
G0	Sound teeth
G1	Z100 (3M ESPE)
G2	Pre-heated Z100 (3M ESPE)
G3	Z350 (3M ESPE)
G4	Pre-heated Z350 (3M ESPE)
G5	Z350XT *flow* (3M ESPE)
G6	RelyX Veneer (3M ESPE)
G7	Direct class IV restoration using Filtek™ Z350 XT (3M ESPE)

A silicon impression of the palatal wall was made for each tooth of group G7, previously to its section. So, the silicone index could be used to rebuild the palatal surface of the tooth, giving reference to the shape of the restoration.

A small amount of putty (Zetaplus, Zhermack) was manually mixed using Powder Free procedure gloves (Unigloves, Brazil) to the catalyst paste, using the proportion indicated by the manufacturer for each material. The mixture was placed in the palatal region of the sound tooth, copying the entire palatal region, the proximal regions, and the incisal border.

4.3 DENTAL FRAGMENT REATTACHMENT TECHNIQUE

In groups G1 to G6, where the fragment reattachment technique was performed, the adhesion protocol described below was performed either on the tooth and the dental fragment.

1. Manual verification of the fragment adaptation to its remnant.(Figure 13) Then, drying both with sterile cotton.
2. Selective application of phosphoric acid CONDAC 37 (FGM, Brazil), with the application of the gel performed only on enamel, for 30 seconds, according to the recommendations of the manufacturer of the adhesive used (selective enamel etching). Subsequently, the acid was removed with an abundant water spray for 60 seconds.(Figures 14 and 15)
3. The surface was dried using a sterile cotton and active application of the Single Bond Universal adhesive (3M, Brazil) using Microbrush applicators (KG Sorensen, Brazil) for 20 seconds was performed , followed by air drying for 5 seconds. (Figures 16 and 17)
4. For groups G1 to G5, light curing of the adhesive was performed with Bluephase G2 (Ivoclair Vivadent, Schaan, Liechtenstein), with a power density of 1.200 mW / cm^2, for 10 seconds.(Figure 18)

After the adhesive procedure, the intermediary composite correspondent to each group was applied over the line surface where the fracture occurred.(Figure 19)

In groups G2 and G4 (bonding with pre-heated composite resin), the composite resin was heated to 69º C using the Hotset heater (Technolife, Brazil), leaving the composite resin syringe inserted in the device to heat syringes by 20min.(Figure 20)

The fragment was adapted manually, and a composite spatula (Millennim, Brazil) was used to remove the excess composite. Afterward, the reattached surfaces were light cured for the time indicated by the manufacturer for each material. The curing time indicated by the manufacturer for each material is described in the following table.

Table 6 Light curing time of each material, per face, according to the manufacturer's recommendations.

MATERIAL	SHADE	CURING TIME (400-1000mW/cm2)
Filtek Z350 XT	A3E	20s
Z100	A3	40s
Filtek Z350XT Flow	A3	20s
RelyX Venner	A3	30s

The light curing device remained charged during all adhesive procedures and, before its use, the intensity of light emitted was verified with a Model 100 Curing Radiometer (Demetron, USA).(Figure 22)

4.4 DIRECT COMPOSITE RESTORATION

In group G7 a class IV restoration was performed using a direct composite resin,. The following adhesion protocol described below was performed:

1. Selective application of phosphoric acid CONDAC 37 (FGM, Brazil), with the application of the gel performed only on enamel, for 30 seconds, according to the recommendations of the manufacturer of the adhesive used (selective enamel etching). Subsequently, the acid was removed with an abundant water spray for 60 seconds.

2. The surface was dried using a sterile cotton and active application of the Single Bond Universal adhesive (3M, Brazil) using Microbrush applicators (KG Sorensen, Brazil) for 20 seconds was performed , followed by air drying for 5 seconds.

A small amount of Filtek ™ Z350 XT (3M ESPE) composite resin, shade A3E, was adapted using a resin spatula (Millennium, Brazil) on the previously made silicone index.

Once the surface of the fracture, after the adhesive procedure was prepared for the restoration, the silicone index with the composite resin was then placed in the tooth. The thin resin layer was adapted with a spatula and cured for 20 seconds, in accordance with the manufacturer's standards. Being the palatal face already defined, the putty index was removed. The restoration was performed following the stratification technique.(Figures 23 and 24)

Small increments of composite resin Filtek ™ Z350 XT (3M ESPE), shade A3D, were applied on the palatal surface, thus reconstructing the area corresponding to the dentin of the tooth. Each increment was polymerized for 40 seconds. The bucal face was reconstructed using Filtek ™ Z350 XT resin (3M ESPE), shade A3E. In this last layer, in addition to the use of the resin spatula, brushes (Tigre, Brazil) were used to better set the material, facilitating the reproduction of the final texture of the tooth. (Figures 25 and 26)

After the restorative procedure, any excesses on the palatal surface were removed with a 3118 diamond bur (KGSorensen, Brazil), attached to an EXTRAtorque 505C high-speed handpiece (KaVo, Brazil). The finishing of the mesial, bucal, and distal regions was done with Sof-Lex ™ Pop-On abrasive discs (3M ESPE)

The restoration was polished with a silicon carbide brush, “cup” format (Occlubrush - Kerr) at low speed.(Figures 27 to 30)

4.5 SAMPLE PREPARATION

Each sample was marked 10 mm from the fracture line, to standardize their inclusion in an aluminum tube (15 mm internal diameter and 35 mm height) which was later connected to the universal testing machine.

The height of the inclusion of the teeth (35 mm) was defined after the pilot tests. The objective was to cover the enamel cemental junction region with acrylic resin, reducing the fracture bias in the cervical area, which is less resistant due to its greater constriction.

The chemically activated acrylic resin (Vipi Flash, Brazil), handled according to the manufacturer's recommendations in a Paladon glass jar (Golgran, Brazil), was poured into each aluminum tube, which was attached to a glass plate covered with double-sided adhesive tape, until filled. Then, the acrylic, when inserted into the tube, did not drain before polymerizing.(Figure 31)

The teeth of the negative control group were kept healthy and inserted in their supports using the same technique used for fractured teeth, leaving 15 mm of the crown not included in the acrylic resin. No additional treatment was performed in this group before the fracture resistance test.

4.6 FRACTURE MECHANICS TESTS

To evaluate resistance to impact, the reattached specimens and the sound teeth were mounted in a universal testing machine (MTS Landmark 370.10, MN, USA). The aluminum tubes were positioned in a stainless-steel device 70 mm in height, with a square base of 70 mm and a 45° inclined plane with a central hole (21 mm in diameter and 33 mm in depth). The teeth were then subjected to a tangential load at 1 mm/min crosshead speed. The load cell used was 5 kN (500 kgF). The antagonistic metal tool was fixed to the universal testing machine and positioned 2 mm from the incisal edge of the labial surfaces of the teeth.

Figure 5 Bovine tooth.

Figure 6 Teeth stored in thymol solution.

Figure 7 Digital caliper used to measure the teeth.

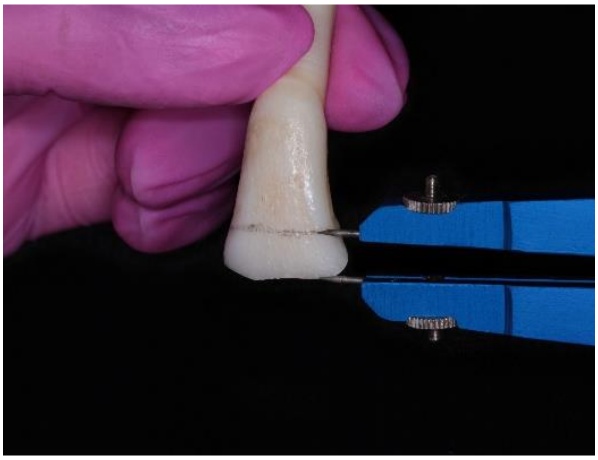

Figure 8 Line traced 5mm from the incisal edge

Figure 9 Fixation of teeth in an acrylic matrix using godiva.

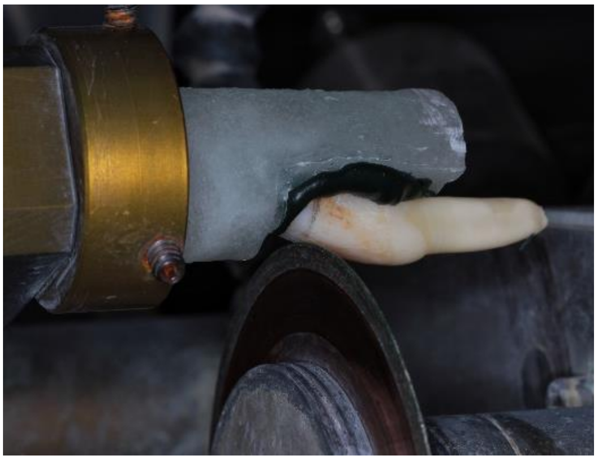

Figure 10 L-support device with attached teeth positioned in the cutting machine.

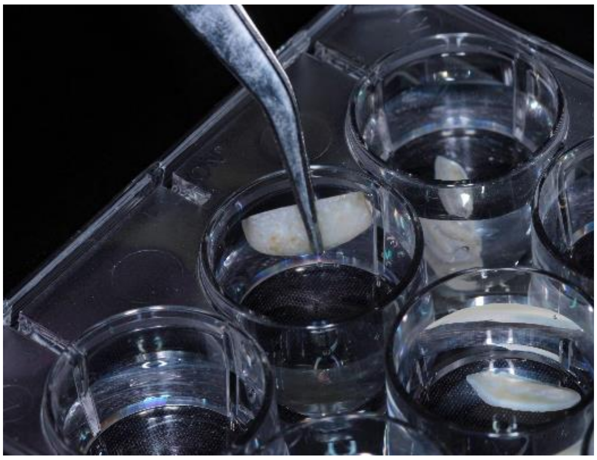

Figure 11 Dental fragments kept in distilled water.

Figure 12 Silicone index.

Figure 13 Manual verification of the fragment adaptation.

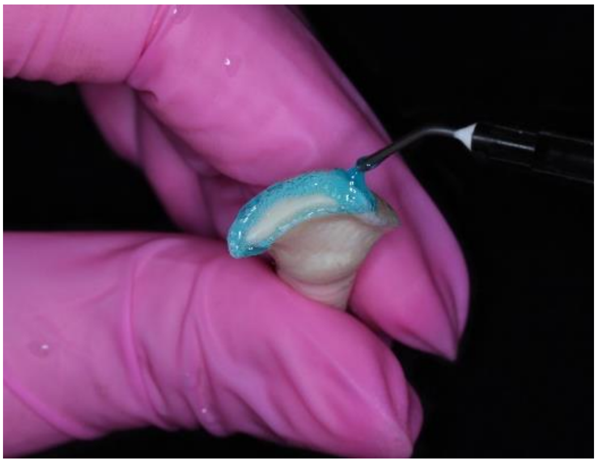

Figure 14 Selective enamel etching.

Figure 15 Spray water to rising.

Figure 16 Drying procedure with dry sterile cotton.

Figure 17 Adhesive protocol.

Figure 18 Light curing at 1200mw/cm^2 .

Figure 19 Resin composite application using a spatula.

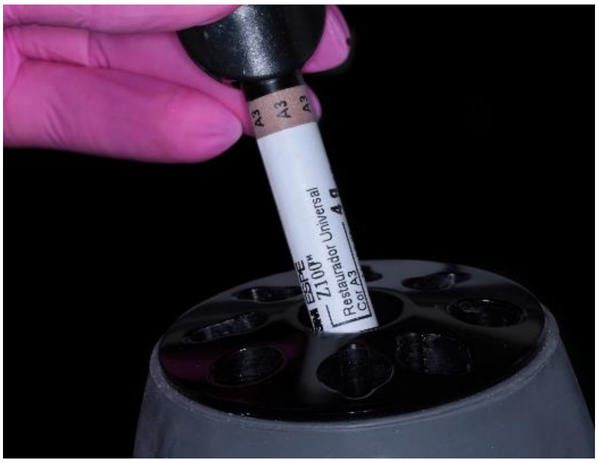

Figure 20 Composite syringe inserted into the heater device (Hotset, Technolife, Brazil).

Figure 21 Excess material being removed.

Figure 22 Light curing of intermediate material at 1200mw/cm^2.

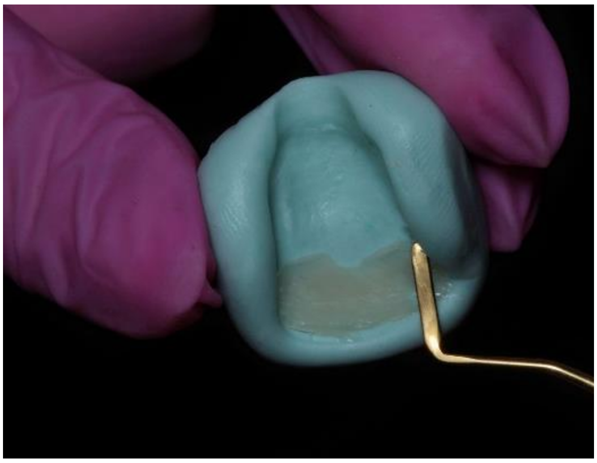

Figure 23 Adaptation of the palatal composite resin on the silicon index.

Figure 24 Palatal face of the restoration.

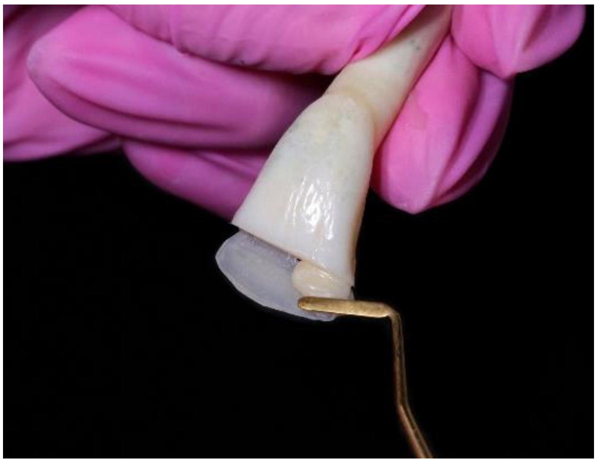

Figure 25 Reconstruction of the intermediate dentin layer.

Figure 26 Reconstruction of the vestibular face.

Figure 27 Remotion of excess composite resin in the palatal surface.

Figure 28 Polishing of vestibular surface using Sof-Lex ™ Pop-O (3M/ESPE).

Figure 29 Polishing using a silicon carbide brush.

Figure 30 Restoration of bovine tooth with direct composite resin.

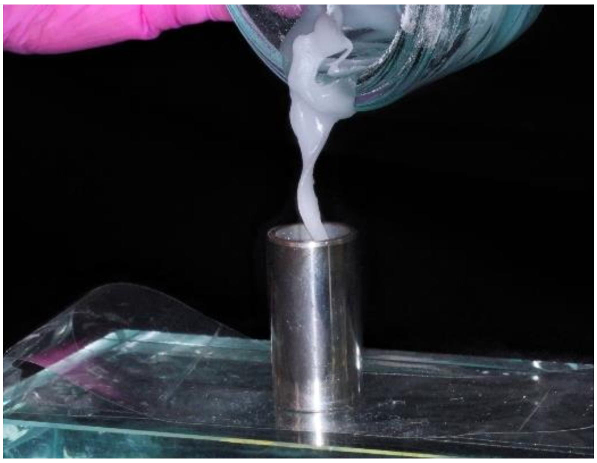

Figure 31 Inclusion of the tooth in an aluminum tube using acrylic resin.

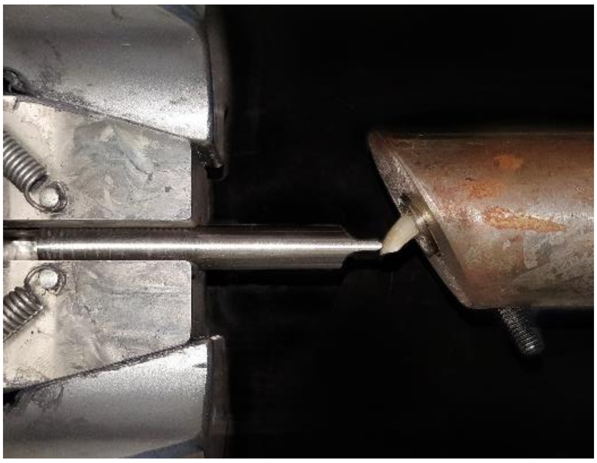

Figure 32 The specimens mounted in a universal testing machine.

4.7 FRACTURE TYPE ANALYSIS

The fractured mode was analyzed using a stereomicroscope at 16xmagnification (Zeiss, Brazil). The fracture modes were classified as adhesive (rupture between substrate / composite interface), cohesive (substrate or material failure) or mixed (cohesive and adhesive failures) after the fracture resistance test.

4.8 STATISTICAL ANALYSIS

The data were submitted to descriptive statistical analysis (mean and dispersion), followed by analytical analysis using one-way analysis of variance (ANOVA) and the Tukey post hoc test at 5% significance.

5.0 RESULTS

The normal distribution of the data was confirmed by the Shapiro Wilk test ($p = 0.12$). Thus, parametric tests were used for statistical analysis of the data (One-way ANOVA and Tukey t-test).

The data obtained were initially analyzed by comparing the experimental groups (reattached and direct restoration) with the control group (sound tooth) by one-criterion variance analysis (control groups), complemented by the Tukey test.

Table 7 Means and standard deviation of fracture resistance (N) of sound teeth and experimental groups (fragment reattachment or direct restoration).

Group	Intervention	Mean (standard-deviation)
G0	Sound	1237.2 (265.7)[a]
G1	Z100	843.9 (179.5)[b]
G2	Preheated Z100	1056.3 (263.2) [a,b]
G3	Z350XT	830.9 (267.7)[b]
G4	Preheated Z350	1026.8 (246.9) [a,b]
G5	Z350XT *flow*	826.4 (212.1)[b]
G6	RelyX Veneer	901.1 (279.1)[b]
G7	Direct Class IV with Filtek™ Z350 XT	864.7 (297.8)[b]

Means followed by the same superscript letters do not differ statistically (Tukey, $p > 0.05$).

The one-way ANOVA test identified differences between the groups ($p = 0.0001$). According Bonferroni test, the control group (G0) showed values of fracture resistance statistically superior to the other experimental groups ($p < 0.05$), except for the groups G2 e G4 (Table 7). Figure 33 presents the box-plot graph for the fracture resistance values of the control and experimental groups.

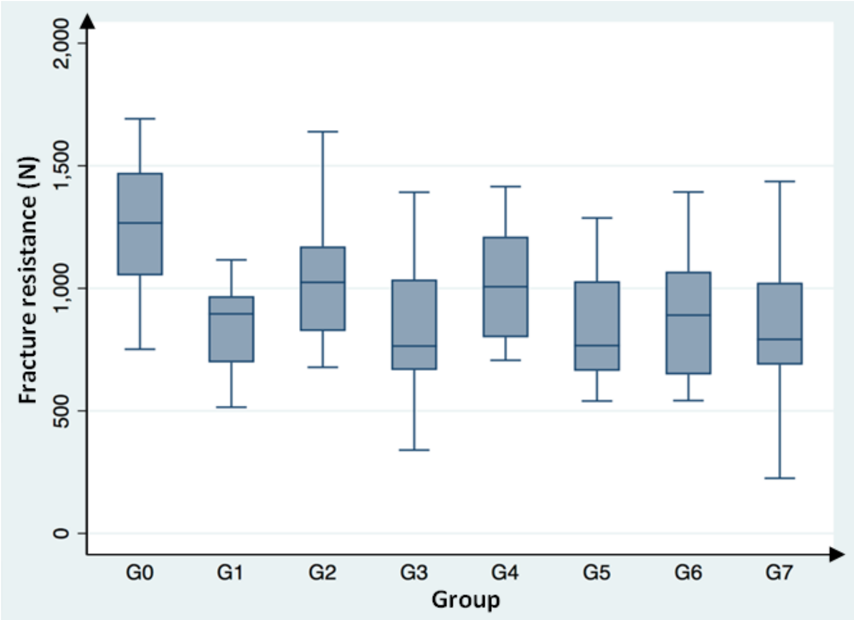

Figure 33 Box-plot graph for the means of fracture resistance values (N) of the control and experimental groups.

To evaluate whether the bonding material (photo-activated cement, conventional, flowable and pre-heated composite resin) influenced the fracture resistance values, a statistical analysis was performed only with groups G1 to G6. There was a statistically significant difference among the groups (one-way ANOVA, p = 0.04).

Table 8 Means and standard deviation of fracture resistance (N) of reattached fragments using intermediate materials .

G1	Z100	843.9 (179.5)[a]
G2	Pre-heated Z100	1056.3 (263.2) [b]
G3	Z350XT	830.9 (267.7)[a,c]
G4	Pre-heated Z350XT	1026.8 (246.9) [b,c]
G5	Z350XT *flow*	826.4 (212.1)[a]
G6	RelyX Veneer	901.1 (279.1)[a,c]

Means followed by the same superscript letters do not differ statistically (Tukey, p> 0.05).

As shown in Table 8, G2 (bonding with pre-heated composite resin Z100) and G4 (bonding with pre-heated composite resin Z350) showed the highest fracture resistance values (p<0.05). For Z100, there was a significant difference when the composite was pre-heated (G1 and G2; p<0.05); while for resin Z350XT (G3 and G4) this difference was not observed (p=0.05). The groups of pre-heated composite resins (G2 and G4) showed significantly higher fracture resistance values than the flowable resin group (G5) ($p<0.05$). The RelyX Veneer resin cement (G6), showed significant difference values when compared to pre-heated Z100 group (G2) ($p>0.05$).

To assess whether the restorative method (fragment reattachment vs. direct composite restoration) influenced the fracture resistance values, a new statistical analysis was performed. There was no statistically significant difference between the bonded or direct restored groups (t-test, p = 0.53).(Table 9)

Table 9 Means and standard deviation of fracture resistance (N) of experimental groups comparing fragment reattachment or direct restoration.

Fragment Reattachment	910.31 (254.8)[a]
Class IV restoration	864.7 (297.8)[a]

Means followed by the same superscript letters do not differ statistically (Tukey, p> 0.05).

The type of fracture was also analyzed using Kruskal-Wallis. There was no difference between the reattached and/or directly restored groups (p = 0.51). All the specimens of the control group presented fractures in the cervical (cohesive) region, whereas the specimens submitted to fragment reattachment and direct restoration presented cohesive, adhesive or mixed fractures.

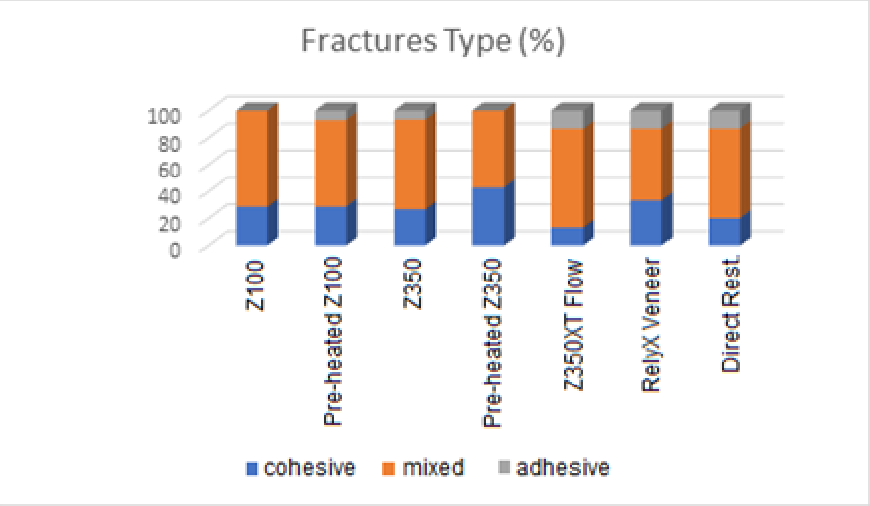

Figure 34 Distribution of fracture pattern for fracture resistance of reattached teeth using different intermediate materials or direct restoration.

6.0 DISCUSSION

Tooth fragment reattachment and direct composite resin are viable options for restore functionally and aesthetically a fractured tooth. Regarding the fragment reattachment technique, the layer formed by the restorative material and the fragment must be continuous, homogeneous, and thin, allowing a good settlement and promoting an effective marginal seal. In addition, the material must have a color compatible with the aesthetic purpose.

In the present study, the influence of both the material used to reattach the fragment and the type of restoration (fragment reattachment vs direct composite resin) was evaluated. The first two null hypotheses were rejected, since there was a difference between the intermediate materials used to bond the fragment (photoactivated resin cement, conventional and flowable composite resins, or preheated conventional resins) and there was a difference between using the same material in the conventional or preheated way. The third null hypotheses were accepted since there was no difference between the techniques of fragment reattachment and direct composite restoration (class IV) regarding the fracture resistance of the tooth.

The control group (G0) showed values of fracture resistance statistically superior to the other experimental groups ($p < 0.05$), except for the groups whose fragments were bonded using preheated resin. In other words, reattaching the fragment using pre-heated composite resin as an intermediate material provided similar fracture resistance to the healthy tooth. Statistical analysis was also performed with groups G1 to G6, to evaluate whether the bonding material influenced the fracture resistance values, and it was observed that G2 (bonding with pre-heated composite resin Z100) and G4 (bonding with pre-heated composite resin Z350) showed the highest fracture resistance values.

Clinical and laboratory reports have mentioned the heating of composite resin, with a high content of inorganic load, as a mechanism to reduce its viscosity and enable the use for cementation purposes. (81) The decrease in viscosity also aims to reduce the thickness of the cementation film, which should be as thin as possible to minimize possible damage to the adhesive interface, as greater stresses develop in the cementation area as the film thickness increases. The viscosity of resin-based restorative materials is dependent on their composition, and the higher the inorganic filler content, the higher the viscosity. (82) (83) The higher viscosity of resins is certainly explained by the larger amount of filler in conventional composite resins when compared to resin cements, which have lower amounts of fillers. Besides, particle type, shape, size, nature of particle surface, and filler spatial arrangement within the resin composite are relevant aspects. (74) This might explain why groups G2 and G4 showed significantly highest fracture resistance values ($p>0.05$).

Another reason for preheating composite resins is the increased degree of conversion due to the heating of the material. According to Daronch et al (84), with the increase in the temperature of the composite, free radicals and polymer chains become more mobile due to the decrease in viscosity and react on a larger scale, resulting in a more complete and more crosslinked polymerization reaction. This increase in the conversion of monomers to polymers can increase the mechanical properties and enhance the wear resistance of the materials.

Many composite resin heating devices are available on the market and are designed to accommodate the composite resin tube, keeping it heated to the desired temperature. In this study, a heating device called HotSet was used, other devices with the same line of operation, such as CalSet (AdDent Inc; Danbury, Connect, USA) are available and are widely used for clinical and laboratory research. A possible flaw of the technique is the time spent to remove the heated material from the device. It has to be sufficient to cool the material and partially recover its viscosity - it is estimated that when a composite is heated to 60° C and removed from the device, the temperature decreases 50% after 2 min and 90% after 5 min. (84)

Concerning the increase of intrapulpal temperature, Daronch at al (85) has shown that the use of pre-heated composite did not produce significantly major in vitro intrapulpal temperatures than composite placed at room temperature. The causative factor attributed to the intrapulpal temperature rise was the application of the curing light, which was found to be more than 5◦C, regardless of the composite temperature at placement. Thus, it appears that pre-heated composite may be used with relative safety regarding intrapulpal temperature rise.

For Z100, there was a significant difference between bonding with or without pre-heating (G1 and G2; $p <0.05$). The composite resin Z100 (3M ESPE) is classified as micro-hybrid with a high content of inorganic filler (around 80%). In Neta et al (86), different properties of materials used for cementation were tested, at 25º and 69ºC, including RelyX Veneer and Z100. It was found that when heating Z100 from 25ºC to

69ºC, the average reduction in its viscosity was 79.3%. The thickness of the film formed when cementing a ceramic indirect restoration with Z100 was 106 µm, which is accepted in the literature – it should be noted that a thicker film of resin composite in this case may not be a clinical issue because this material is designed to have color stability and abrasion resistance. (87) (88)

The Z100 resin is mainly composed of bisphenol-A glycidyl methacrylate (Bis-GMA), a monomer with two aromatic groups in its structure, which increase its viscosity and make it less flexible compared to the other monomers used in dental composites. Besides, the presence of hydroxyl groups (-OH) in Bis-GMA forms strong intermolecular hydrogen bonds. The pre-heating of the Z100 resin seems to break these hydrogen bonds and increase the mobility of the monomers, since the viscosity of the composite is reduced by the heat. (89)

When compared to bonding with the resin cement RelyX Veneer, Z100 has shown greater fracture resistance values. This way, Z100 might be an available option for cementing ceramics and for bonding the dental fragment, replacing RelyX Veneer cement, which has a high cost and less filler particles, resulting in lower mechanical properties when compared to Z100 resin. Besides, there was no statistically significant difference between using RelyX Veneer (G6) or flowable resin (G5), probably due to the similar mechanical properties of the flowable resin and the resin cement, since these materials present fewer filler particles in their composition.

For resin Z350XT (G3 and G4) there was no significant difference between bonding with or without pre-heating ($p>0.05$). Filtek Z350XT contains less viscous monomers in addition to Bis-GMA, like ethoxylated bisphenol-A dimethacrylate (Bis-EMA). Bis-EMA is a monomer analogous to bis-GMA, also containing two aromatic groups in its structure, but without the two hydroxyl groups (-OH). Lack of the -OH in bis-EMA has been suggested to increase its flexibility, due to the lack of ability to form strong intermolecular hydrogen bonds leading to an increased degree of conversion. Thus, Filtek Z350XT resin may have achieved a high degree of conversion with its conventional use, leading to similar fracture strength values in G3 and G4. (89)

Furthermore, Fóes-Salgado (83) tested the effect of pre-polymerization temperature and energy density on the marginal adaptation, degree of conversion, flexural strength, and polymer cross-linking of Filtek Z350 under 68ºC. The composite pre-heating to 68◦C did not improve any of those properties but yielded enhanced marginal adaptation. Nanofilled composite shows high translucency levels due to little light scattering effect, which can favor the attainment of high conversion values even when the composite was not preheated.

There was no statistically significant difference between bonding or direct restoring the tooth (t-test, p = 0.53). This finding does not agree with the majority of previous studies, where resin composite restoration was the most satisfactory technique regarding fracture strength. (11) (28) A possible justification for the result found in this study is that when comparing the groups where the fragment was reattached (G1 to G6) vs the group where the teeth were restored (G7), the analysis was performed by putting groups G1 to G6 together (including the groups with pre-heated resin, G2 and G4), which may have raised the mean fracture resistance values for the reattached group. On the other hand, Andreasen et al (90) have shown similar survival time for resin composite restoration and reattachment of the fragment, making the reattachment technique preferable over direct restoration when the tooth fragment is available, since achieving the correct contours and establishing interproximal contacts are complex, requiring longer chair time.

When it comes to fracture types, all specimens of Group G0 (sound teeth) showed cervical fracture, which occurs since it is the area of most constriction and less volume of the teeth. Higher frequency of adhesive fractures was found in Groups G5 and G6, being compatible with previous findings, in which the teeth that presented adhesive-type fractures obtained lower values of fracture resistance. (10) Moreover, the materials used in G5 and G6 (flowable composite and resin cement, respectively) contain large amounts of diluting monomers, like triethyleneglycol dimethacrylate (TEGDMA) and urethane-dimethacrylate (UDMA), which results in a less viscous but brittle material.

Regarding the methodology, the use of bovine teeth in this study was supported by Nogueira et al (91), who stated that bovine teeth present morphology, micro-hardness, and mineral composition similar to human teeth and are also easier to obtain - dispensing the need for approval by the ethics committee, according to Brazilian law. The tooth fragments were obtained by sectioning with a diamond disk instead of fracturing. Badami et al (92) and Reis et al (11) stated that the surface of a sectioned tooth is different from that of a fractured tooth: in a fractured region, the fracture line tends to run parallel to the direction of enamel prisms, whereas the direction in a sectioned tooth is dictated by the position of the disk. (58) However, this direction does not faithfully represent the actual situation of the trauma, since it does not always occur linearly or with perfect adaptation. (4) (12) Nevertheless, fracture simulation with a cutting disk allowed the standardization of the fragments required to reduce confounding bias.

The 1 mm/min compression stress applied to the specimens in the universal test machine was another limitation of the present study, since it did not simulate the clinical failure mode. (93) In addition, spontaneous fracture most often occurs quickly and with an immediate overload on the tooth. In contrast, the intentional fracture performed in the study was at a slow and steady speed and with a load that increased progressively as the contact of the machine with the tooth increased. However, dental trauma does not always result from high energy impact. Malocclusion and parafunctions such as bruxism can expose the teeth to constant overload, which can result in coronal fracture.

The use of the reattachment technique with no prior preparation was based on systematic reviews, reasoning that no preparation and an adhesive system associated with an intermediate resin composite with good mechanical properties can restore part of the resistance of the fractured tooth. (60) (61)

Regarding the hydration of the fragment, both the hydration solution (water) and the time of immersion (1h) was based on the clinical routine (representing the time intervals between the time the DT occurred and the time the patient reached the dental office). (25)

Since uncomplicated crown fractures reaches only the enamel or the enamel and dentin, without pulp involvement, a self-etching aproach may be the preferred choice to avoid pulp damage and dentin sensitivity, avoiding the use of phosphoric acid directly on the dentin. These systems are recommended since demineralization and infiltration of resin monomers occur simultaneously. However, the selective application of phosphoric acid to the enamel surface has been recommended, since acid etching of the enamel promotes dissolution of the prisms, thus increasing porosity and surface energy, in order to obtain adhesive penetration, and enabling the formation of a uniform hybrid layer. (70) As for dentin, multi-mode 'universal' adhesives can achieve substantial bonding to dentin, regardless of the used modes (either etch-and-rinse or self-etch). (95)

The proposed technique for fragment reattachment and direct composite restoration was selective etching in enamel, followed by active application of Single Bond Universal (3M/ESPE, SP, Brazil) as a self-etching adhesive, which contains phosphorylated methacrylate monomers (MHP or MDP) to allow the acidity for the self-etching capability. Moritake et al, comparing the penetration status of the resin tags with active and inactive application in self-etch mode, concluded that the resin tag penetration with inactive application was much lower than that with active application. So, active application, as used in this research, is effective in enhancing the dentin bond durability of universal adhesives. (96)

Further clinical studies should address the longevity of fractured crown restorations bonding the tooth fragment with different pre-heated composites to create consistent clinical protocols.

7.0 CONCLUSIONS

The reattachment technique using preheating composite resins as intermediate material could approximate the immediate impact strength of the restored teeth to that observed in the sound teeth. Direct restorations showed similar resistance fracture than reattached fragments.

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APPENDIX

Declaração de Origem dos Dentes Bovinos

Zanchetta Indústria de Alimentos Ltda, inscrito no CNPJ 33.920.401/0001-19, por este instrumento informa aos órgãos de ética e pesquisa em animais que os 200 dentes bovinos, abate do dia 31/08/2019, dos lotes 01, 02, 03, 04 e 05, foram comercializados por Nelson Queiroz 01536909840, inscrito no CNPJ 33.837.015/0001-68, para teste "in vitro", para a pesquisa denominada: "Comparação da resistência à fratura de dentes submetidos à colagem do fragmento utilizando diferentes materiais ou submetidos à restauração direta".

Os dentes pertencem a bovinos da raça Nelore, com cerca de 3 anos de idade e 250 kg de peso limpo, tratados dentro dos rígidos padrões de qualidade, e rastreamento sob fiscalização do Ministério da Agricultura – SIF 1758.

Atenciosamente,

José Maurício Soares Pardo
Gerente Comercial

Bauru, 29 de outubro de 2020.

Zanchetta Indústria de Alimentos Ltda
Jardim Mendonça | Bauru/SP
Brasil

Av. Rosa Malandrino Mondelli, 10-45
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PRESS RELEASE

O trauma dental pode ser considerado um problema de saude publica uma vez que apresenta alta prevalência e acomete crianças, adolescentes e adultos, independente de classe social, etnia ou gênero. Apesar dos resultados dos estudos a respeito apresentarem resultados variados, os gênero masculino é o mais afetado. O tipo de lesão pode variar de acordo com a idade, sendo o tipo de fratura mais prevalente na dentição permanente a fratura de coroa. Dessa forma, existem estudos mostrando várias alternativas de tratamento, sendo a colagem do próprio fragmento do dente uma alternativa viável. Porém, até então, nenhum material usado para colar o dente recuperava sua resistência como a de um dente saudável. Esse estudo testou diferentes materiais para realizar essa colagem, com o objetivo de identificar qual seria o material mais que possibilitasse maior resistência do dente. Foram testadas diferentes resinas compostas (usadas no consultório odontológico para restaurações convencionais) e um cimento (usado para cimentar facetas). Outra estratégia foi o uso de resina composta previamente aquecida antes de fazer a colagem. Percebeu-se que, nesses grupos, o dente desenvolveu uma maior resistência a fratura. Um outro fator que tem que se levar em conta quando não é possível colar o próprio fragmento, devido ao fato do mesmo se encontrar em vários pedaços ou do paciente não encontra-lo. Dessa forma esse trabalho verificou a possibilidade de restaurar o dente fraturado utilizando resina composta direta, e se pode observar que os resultados de ressietncia à fratura foram similares aos grupos em que se colou o fragmento. Conclui-se, então, que a técnica de colagem do fragmento utilizando materiais intermediários, principalmente com resina aquecida, é uma alternativa viável e que assegura uma ótima resistência, similar ao dente sadio. Da mesma forma, quando da impossibilidade de colar o próprio fragmento, fazer a restauração do dente com a resina composta também se mostrou uma técnica eficaz. Estudos clínicos a longo prazo utilizando essas técnicas devem ser realizados para verificar os achados desse estudo laboratorial.