FRACTURE RESISTANCE OF CORONAL FRACTURE FRAGMENT REATTACHMENT VS DIFFERENT COMPOSITE RESTORATIONS IN ANTERIOR CROWN FRACTURES- AN IN VITRO STUDY

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Abstract

Introduction: Esthetics is prime concern for all ages, especially for teenager, adolescent, puberty to young adults. At these ages, there is high risk of fracture of anterior teeth reported in the literature. Various methods are used for esthetic correction of these fractured teeth. This article focuses on fracture resistance of reattachment (of fracture fragment) Vs composite build-up and their comparative evaluation.

Aim and objectives: To evaluate and compare the fracture resistance of four different restorative techniques including reattachment with dual- cure resin cement and micro- hybrid composite resin and restorative composite build- up with micro-hybrid and nano- hybrid composites.

Materials and method: Fifty sound caries- free human maxillary central incisors were selected for the study (n=50). Control group: Group I: Intact teeth fractured directly with a Universal Testing Machine. Experimental group: Group II: Reattachment of fractured fragment with dual- cure resin cement with an internal dentinal groove preparation.
Group III: Reattachment of fractured fragment using micro-hybrid composite with an internal dentinal groove preparation.
Group IV: Composite build- up of fractured teeth with micro-hybrid composite with an enamel bevel preparation.
Group V: Composite build- up of fractured teeth with nano-hybrid composite with an enamel bevel preparation

Result: Group V in experiment group showed highest fracture resistance while group II showed lowest.

Summary and conclusion: The fracture resistance of teeth restored by two different reattachment techniques showed highly statistically significant difference. Reattachment with micro-hybrid composite (29.02 ± 2.55 KgF) attained higher fracture resistance than reattachment with dual-cure resin cement (20.00 ± 3.01KgF). The fracture resistance of teeth restored by two different composite build up techniques showed no statistically significant difference. Composite build- up with nano- hybrid composite (40.90 ± 3.86 KgF) attained higher fracture resistance than micro- hybrid composite (39.21 ± 4.00 KgF). None of the experimental group showed comparable fracture resistance to that of control group(43.72+_9.15KgF)

Keywords: Fracture resistance, reattachment, Composite build-up.

Introduction

Esthetics is of utmost importance to the patient and dentists, and we cannot neglect the importance of adequately restoring the esthetic elements of the tooth. Improvements in esthetic materials allow us the opportunity of excellent results in restoring the damaged tooth. Conservative restoration of fractured anterior teeth provides one such challenge.

Coronal fracture by trauma has been reported to account for up to 92% of all traumatic injuries to permanent dentition.[1]Recent investigations into the incidence of dental trauma, especially in pediatric and adolescent populations, have suggested fractures of the crown of an anterior tooth is common and affects up to one-third of the patients in this age group.[2] In addition, some studies have reported estimates of about one out of every four persons, under the age of 18, would sustain a traumatic dental injury in the form of an anterior incisal fracture.[3,4]

The most affected teeth are maxillary incisors (80% central incisors and 16% lateral incisors) due to their anterior position and protrusion caused by the eruptive process (Andreasen & Andreasen, 1993).[5] Gender also plays a major role on the incidence of traumas. It has been reported males are more frequently affected than females, particularly in the maxillary incisors.[1]

No single dental disturbance has a greater psychological impact on the patient than the loss or fracture of anterior teeth. Techniques that speed and simplify treatment, restore esthetics and improve long- term success rates are therefore of potential value and should be considered.

The most conservative restorative options- namely fragment re-bonding and composite resin restoration were not available until the introduction and adaptation of the acid- etch technique and the development of resin- based adhesives and composites in the late 1950's and 1960's,[6]which has been introduced by Dr. Michael Buonocore.

One of the options for managing coronal tooth fractures, especially when there is no or minimal violation of the biological width, is the reattachment of the dental fragment when it is available. Tooth fragment reattachment offers a conservative, cost effective restorative option that can provide good and long-lasting esthetics (because the tooth's original anatomic form, color, and surface texture are maintained), can restore function, can result in a positive psychological response, and is a reasonably simple procedure. [7] In addition, tooth fragment reattachment allows restoration of the tooth with minimal sacrifice of the remaining tooth structure. Furthermore, this technique is less time-consuming and provides more predictable long-term wear. [8]

The first to describe in detail the clinical procedure of the restoration of complicated and uncomplicated coronal fractures, with the fractured incisor fragment, was Andreasen et al [9]. This technique was baptized as the 'GLUMA technique' and was applied to the restoration of 76 permanent incisors.[10] Many techniques were followed for fracture reattachments of teeth.[11]

With the advent of new systems of dentinal bonding and the technique for acid- etching the enamel, a restoration with filled resins is, without a doubt, the treatment of choice whenever the fractured fragment is no longer available. There are advantages of using composite resins for the restorations of enamel- dentin fractures, such as shortening chair time, biocompatibility of the material, low cost, and minimal hard tissue removal. [12] The incremental technique, through the application of successive layers of resin, yields a restoration more opaque in the dentinal region and more translucent in the region of the incisor's margin. It is capable of restoring a natural translucence, shape and texture to the traumatized tooth. [10] The polish ability of composite resins has been also improved by the new developments of inorganic particle size and ratio. [12]

Despite the advances, use of composite resin to restore anterior tooth fractures still presents many shortcomings. For example, composites shrink upon curing, may discolor over extended periods of time, and may not fully restore the fracture resistance of the intact tooth.[13]The long- term seal of class IV composite restoration remains modest in terms of duration and esthetics. Browning and Dennison (1996) [10] tried to clarify the causes of failure in these restorations and concluded that the principal reasons are related to the adhesive systems used (failure of

the bonding accompanied by the fracture of the filled resin) or dependent on the material used (cohesive fracture of the filled resin).

Fracture resistance of a material is a measure of its ability to retard crack initiation and propagation. High fracture resistance of restorative material is required in clinical situations where high impact stresses are experienced and incisal angle restoration of a fracture in anterior tooth is one such demanding situation. [14] Generally, the resistance to fracture of the restored anterior fractured tooth will not be the same as the intact teeth. However, depending on the restorative technique and the materials used, resistance to fracture could be achieved similar to non-fractured intact teeth.[5]

Therefore, the present study was undertaken to study the fracture resistance of different materials to restore the fractured anterior teeth using reattachment and composite build- up with different methods. This study will help us as clinicians to choose one of the most viable technique and material for the treatment of uncomplicated anterior crown fractures.

Aims and objectives

The aim of this in vitro controlled trial study is to compare the fracture resistance of four different restorative techniques including reattachment with dual- cure resin cement and micro- hybrid composite resin and restorative composite build- up with micro- hybrid and nano- hybrid composites.

The objectives of this study are:

1. To evaluate and compare the fracture resistance of intact sound teeth and restoration of anterior fractured teeth by different reattachment and composite build up techniques.
2. To compare the fracture resistance of teeth restored by two different reattachment techniques.
3. To compare the fracture resistance of teeth restored by two different composite build-up techniques.
4. To compare the fracture resistance of teeth restored with reattachment and composite build-up techniques

Materials and method

Sample collection:

A total of fifty sound caries- free human maxillary central incisors extracted due to periodontal diseases were collected from the out- patient Department of Oral and Maxillofacial Surgery, Nair Hospital Dental College, Mumbai Maharashtra, India. Teeth free from visible cracks or other structural defects were selected under optical magnification of 4x. Teeth were immersed in a 3% solution of sodium hypochlorite for 3 minutes and then washed in physiologic saline solution. Debris, soft tissue and calculus were cleared from the external tooth surface using ultrasonic scaler and teeth were stored in physiologic saline solution until the beginning of the study (Farik and others, 1998b; 1999).[5]

Grouping of the samples:

The sample was divided into 1 control and 4 experimental groups with each group comprising of 10 teeth (n= 10).

Control group:

Group I: Intact teeth were fractured directly with a Universal Testing Machine.

Experimental group:

Group II: Reattachment of fractured fragment with dual- cure resin cement with an internal dentinal groove preparation.

Group III: Reattachment of fractured fragment using micro-hybrid composite with an internal dentinal groove preparation.

Group IV: Composite build- up of fractured teeth with micro-hybrid composite with an enamel bevel preparation.

Group V: Composite build- up of fractured teeth with nano-hybrid composite with an enamel bevel preparation.

Sample preparation:

The roots and part of the crown, up to 1 mm above the cemento- enamel junction, were placed in a cylindrical mold, with an internal diameter of 15 mm and were filled with acrylic resin (DPI-RR Cold cure, B.B.T. Co. Ltd., Mumbai, India). The mesio- incisal or disto- incisal part of teeth in group II, III, IV and V were cut at a distance of 3 mm from the incisal edge, in order to achieve uncomplicated class II Ellis fracture. These cuts were made using a diamond disc in a micromotor straight handpiece (KaVo Kerr, Germany). The teeth and their fragment were kept in 0.9% saline (Baxter Co. Mississauga Canada) solution until the restoration procedure was performed.

Restoration of experimental groups:

Group II: Prior to reattachment, an internal dentinal groove (1 mm deep, 1mm wide) was placed within the fragment and the remaining tooth by means of a flat end cylindrical diamond bur (SS White SF41, FG 835010, Wadhwan, Gujrat, India) with a high speed handpiece. Both the tooth and the fragment were etched with 37% phosphoric acid (Scotchbond etchant, 3M ESPE India Ltd.) for 15 secs according to manufacturer's instructions. After washing and gentle drying, maintaining the dentin moist, dentine adhesive system (Adper™ Scotchbond Multipurpose, 3M ESPE India Ltd.) was applied. It was followed by placement of mixed catalyst and base pastes of the dual- cure resin cement (RelyX™ ARC, 3M ESPE India Ltd.) over the conditioned surface and within the internal dentinal groove. The coronal fragment was adapted to the remaining tooth structure and reattached using hand pressure. The excess material was removed before polymerization. The resin cement was polymerized for 40 secs in each surface, buccal and palatal, with a light curing unit (Hilux 200, Heraeus, Kulzer, Delhi, India, intensity of 400 mW/cm^2).

Group III: Prior to reattachment, an internal dentinal groove (1 mm deep, 1mm wide) was placed within the fragment and the remaining tooth by means of a flat end cylindrical diamond bur (SS White SF41, FG 835010) with a high-speed hand piece. Both the tooth and the fragment were etched with 37% phosphoric acid (Scotchbond etchant, 3M ESPE) for 15 secs according to manufacturer's instructions. After washing and gentle drying, maintaining the dentin moist, dentine adhesive system (Adper™ Scotchbond Multipurpose, 3M ESPE) was applied. It was followed by placement of micro-hybrid composite (Filtek™Z250,3 MESPE) over the conditioned surface and within the internal dentinal groove. The coronal fragment was adapted to the remaining tooth structure and reattached using hand pressure. The excess material was removed before polymerization. The micro-hybrid composite was polymerized for 40 secs in each surface, buccal and palatal, with a light curing unit (Hilux 200, Heraeus, Kulzer, intensity of 400 mW/ cm^2).

Group IV: A 45^0 bevel extending 1 mm on the buccal surface was prepared using a tapered fissure diamond finishing bur (SS White, FG 850F016) with a high-speed hand piece, under air water cooling. Both the tooth and the fragment were etched with 37% phosphoric acid (Scotchbond etchant, 3M ESPE) for 15 secs according to manufacturer's instructions. After washing and gentle drying, maintaining the dentin moist, dentine adhesive system (Adper™ Scotchbond Multipurpose, 3M ESPE) was applied. Composite build- up with micro- hybrid composite (Filtek™ Z250, 3M ESPE) was done. Restorations were made following incremental technique (approximately 3 to 4 increments). Each increment was light- cured for 40 secs in each surface, buccal and palatal, with a light curing machine (Hilux 200, Heraeus, Kulzer, intensity of 400 mW/ cm^2). The teeth were finished and

polished with flexible discs (Sof-Lex Pop On polishing disks, 3M dental products, St Paul MN), 24 hours after the restorative procedure.

Group V: A 45^0 bevel extending 1 mm on the buccal surface was prepared using a tapered fissure diamond finishing bur (SS White, FG 850F016) with a high-speed hand piece, under air water cooling. Both the tooth and the fragment were etched with 37% phosphoric acid (Eco- etch, Ivoclar Vivadent) for 15 secs according to manufacturer's instructions. After washing and gentle drying, maintaining the dentin moist, dentine adhesive system (Te- Econom Bond, Ivoclar Vivadent) was applied. Composite build- up with nano- hybrid composite (Tetric EvoCeram, Ivoclar Vivadent) was done. Restorations were made following incremental technique (approximately 3 to 4 increments). Each increment was light- cured for 40 secs in each surface, buccal and palatal, with a light curing machine (Hilux 200, Heraeus Kulzer, intensity of 400 mW/ cm^2). The teeth were finished and polished with flexible discs (Sof- Lex Pop On polishing disks, 3M dental products, St Paul MN), 24 hours after the restorative procedure.

Thermocycling procedure:

All restored specimens were kept in physiologic saline solution and subsequently subjected to thermocycling [150 x; (0- 55 ±2)^{0}C; dwell time = 30 secs, transfer time = 10 secs]. [23]

Fracture of the restored teeth:

A perpendicular load (90^0) was applied at the bonded area in a buccal to lingual direction by means of a small stainless ball of 2 mm^2 diameter with a cross- head speed of 1 mm min^{-1}, placed at the end of a jig held in Universal Testing Machine (Instron 3345 Universal Testing Machine, model No.- 2519- 07). The force required to fracture each tooth was recorded in KgF.

The results were tabulated and statistically analyzed using ANOVA and Tukey's post hoc test.

Failure mode of each specimen was analyzed visually and categorized as one of the following modes: [30]

1. Adhesive failure (A): Failure at the tooth- resin interface.
2. Cohesive failure (C): Failure within the resin restoration or failure below the cemento-enamel junction.
3. Mixed(M): Other failures.

Figure no. 1: Sample mounted in Instron Universal Testing machine

Details of the test materials:

Code	Material	Composition	Batch/lot no.
A	Scotchbond etchant, 3M ESPE.	37% phosphoric acid	N141149
B	Adper™ Scotchbond Multipurpose Adhesive system, 3M ESPE.	Primer: Water- 40- 50% by wt, 2- hydroxyethyl methacrylate (HEMA)- 35- 45% by wt, Copolymer of acrylic and itaconic acids- 10- 20% by wt. Adhesive: Bisphenol a diglycidyl ether dimethacrylate (BISGMA)- 60- 70% by wt, 2-hydroxyethyl methacrylate (HEMA)- 30- 40% bywt.	N123730 N132509
C	RelyX™ ARC dual cure resin cement, 3M ESPE.	Paste A: Silane treated ceramic- 60- 70% by wt, TEGDMA- 10- 20% by wt, BISGMA- 10- 20% by wt, silane treated silica- 1- 10% by wt, functionalized dimethacrylate polymer- 1- 10% by wt,2- benzotriazolyl- 4 –methylphenol < 1% by wt, 4-(dimethylamino)-benzene-ethanol <1% by wt. Paste B: Silane treated ceramic- 55-	N114375
		65% by wt, TEGDMA- 10- 20% by wt, BISGMA- 10- 20% by wt, silane treated silica- 1- 10% by wt, functionalized dimethacrylate polymer- 1- 10% by wt,2- benzotriazolyl- 4 –methylphenol < 1% by wt, benzoyl peroxide <1% by wt.	
D	Filtek™ Z250 (Shade A2), 3MESPE	Silane treated ceramic- 75- 85% by wt, Bisphenol a polyethylene glycol diether dimethacrylate (bisema6)- 1- 10% by wt, Diurethane dimethacrylate (UDMA)-1- 10% by wt, Bisphenol a diglycidyl ether dimethacrylate (BISGMA)- 1- 10% by wt, Triethylene glycol dimethacrylate (TEGDMA)-< 5% by wt.	09J14S
E	Eco-Etch, Ivoclar Vivadent	37% phosphoric acid.	M61593
F	Te- Econom Bond, Ivoclar Vivadent	Mixture of dimethacrylates, alcohol, phosphonic acid acrylate, HEMA (hydroxyethyl methacrylate), SiO2, initiators and stabilizers	M44067
G	Tetric Evoceram (Shade A2), Ivoclar Vivadent	Paste of dimethacrylates, inorganic fillers, copolymer, ytterbiumtrifluoride, initiators, stabilizers and pigments.	M11725

Technique description and sequence of materials:

Groups	Technique	Description	Sequence of material(code)
I		Intact teeth fractured directly with a Universal Testing Machine.	
II	Reattachment	Reattachment of the fragment with internal dentinal groove preparation in the tooth as well as the fragment.	A + B + C
III	Reattachment	Reattachment of the fragment with internal dentinal groove preparation in the tooth as well as the fragment.	A + B + D
IV	Composite build-up	Composite build- up with enamel bevel at 45^0 in the buccal surface.	A + B + D
V	Composite build-up	Composite build- up with enamel bevel at 45^0 in the buccal surface.	E + F + G

Results

The present, in vitro, controlled trial study was conducted to compare the fracture resistance of four different restorative techniques including reattachment with dual- cure resin cement and micro- hybrid composite resin and restorative composite build- up with micro- hybrid and nano- hybrid composites.

The values of force required to fracture samples of control group and experimental groups (after restoration) (in KgF) are shown in table 1 and graph 1.

The mean values and standard deviation (SD) of the force required to fracture each of the five groups of samples are shown in table 2 and graph 2.

Fractured resistance of various groups compared to Group I is shown in table 3 and graph 3.

The difference in the forces required to fracture the intact and restored teeth were analyzed by ANOVA followed by post hoc Tukey's test. A P-value of less than 0.05 was considered for statistical significance.

The results obtained with ANOVA test are shown in table 4. The P value obtained was ($P<0.05$). This indicates that there is a highly significant statistical difference between the groups.

The results obtained with Post Hoc Tukey's test are shown in table 5.

Group I: Intact teeth fractured directly with a Universal Testing Machine: The mean force required to fracture sound teeth was 43.72 ± 9.15 KgF (Table 2).

Group II: Reattachment of fractured fragment with dual- cure resin cement with an internal dentinal groove preparation: The mean force required to fracture the restored teeth with this method was 20.00 ± 3.01KgF (Table 2). The fracture resistance obtained with this group was only 45.74 % of the group I (Table 3). This indicates restoration of fractured fragments by reattaching with dual- cure resin cement does not attain even one half of the fracture resistance of control intact teeth.

The statistical comparison of group II with groups I, III, IV and V showed highly statistically significant difference ($P < 0.05$).

Group III: Reattachment of fractured fragment using micro-hybrid composite with an internal dentinal groove preparation: The mean force required to fracture the restored teeth with this method was 29.02 ± 2.55 KgF (Table 2). The fracture resistance obtained with this group was 66.37% of the group I (Table 3). This indicates restoration of fractured fragments by reattaching with micro- hybrid composite attains more than half of the fracture resistance of control intact teeth.

The statistical comparison of group III with groups I, II, IV and V showed highly statistically significant difference ($P < 0.05$).

Group IV: Composite build- up of fractured teeth with micro-hybrid composite with an enamel bevel preparation: The mean force required to fracture the restored teeth with this method was 39.21 ± 4.00 KgF (Table 2). The fracture resistance obtained with this group was 89.68 % of the group I (Table 3). This indicates restoration of fractured fragments by composite build- up technique using micro- hybrid composite attains a high fracture resistance which is very close to that of control intact teeth.

The statistical comparison of group IV with groups II and III showed highly statistically significant difference ($P < 0.05$) and with group I and V showed no statistically significant difference ($P > 0.05$).

Group V: Composite build- up of fractured teeth with nano-hybrid composite with an enamel bevel preparation: The mean force required to fracture the restored teeth with this method was 40.90 ± 3.86 KgF (Table 2). The fracture resistance obtained with this group was 93.54 % of the group I (Table 3). This indicates restoration of fractured fragments by composite build- up technique using nano- hybrid composite attains a high fracture resistance which is very close to that of control intact teeth.

The statistical comparison of group V with groups II and III showed highly statistically significant difference ($P < 0.05$) and with group I and IV showed no statistically significant difference ($P > 0.05$).

Table 6 shows the failure mode of each specimen:

1. Adhesive failure (A): Failure at the tooth- resin interface.
2. Cohesive failure (C): Failure within the resin restoration or failure below the cemento- enamel junction.
3. Mixed(M) failure: Other failures.

Table 7 and graph 4 shows the % of type of failures in each of the 4 groups.

The results of the study showed that none of the techniques used in the study attained fracture resistance equal to the sound teeth. The fracture resistance of teeth restored by two different reattachment techniques showed highly statistically significant difference. Reattachment with micro- hybrid composite (29.02 ± 2.55 KgF) attained higher fracture resistance than reattachment with dual- cure resin cement (20.00 ± 3.01KgF). The fracture resistance of teeth restored by two different composite build up techniques showed no statistically significant difference. Composite build- up with nano- hybrid composite (40.90 ± 3.86 KgF) attained higher fracture resistance than micro- hybrid composite (39.21 ± 4.00 KgF). The fracture resistance of teeth restored with composite build- up techniques was higher than the two reattachment techniques.

Table 1: Force required to fracture samples of control group and experimental groups (after restoration) (in KgF):

Sample No.	Group I	Group II	Group III	Group IV	Group V
1.	36.50	16.73	26.71	43.76	43.37

2.	58.90	19.01	32.38	34.81	35.63
3.	39.19	24.34	31.49	37.11	44.24
4.	38.36	22.36	28.64	36.92	43.40
5.	39.92	19.34	32.19	39.53	34.11
6.	54.62	23.11	28.76	38.27	45.96
7.	35.30	18.67	26.42	43.39	40.72
8.	37.79	22.14	30.92	40.63	39.58
9.	39.95	19.78	27.18	32.78	38.85
10.	56.70	14.61	25.57	44.92	43.19

Table 2: Mean values of the force required to fracture each of the five groups of samples.

Groups	Group I	Group II	Group III	Group IV	Group V
Mean	43.7230	20.0090	29.0260	39.2120	40.9050
SD	9.15190	3.01172	2.55267	4.00195	3.86161
Minimum	35.30	14.61	25.57	32.78	34.11
Maximum	58.90	24.34	32.38	44.92	45.96

Table 3: Fracture resistance of various groups compared to group 1:

	% of fracture resistance compared to Group I (Intact teeth)
Group II	45.74 %
Group III	66.37 %
Group IV	89.68 %
Group V	93.54 %

Table 4: ANOVA test

	Sum of squares	Degree of freedom	Mean square	F	Significance (P)
Between groups	3882.163	4	970.541	37.251	.000
Within groups	1172.444	45	26.054		
Total	5054.607	49			

Table 5: Post Hoc Tukey's Test (Multiple comparisons)

(I)Group	(J)Group	Mean difference (I- J)	Std error	Significance	95% confidence interval	
					Upper bound	Lower bound
Grp_1	Grp_2	23.71400 *	2.28273	.000	17.2277	30.2003
	Gr p_3	14.69700 *	2.28273	.000	8.2107	21.1833
	Grp_4	4.51100	2.28273	.294	-1.9735	10.9973
	Grp_5	2.81800	2.28273	.731	-3.6683	9.3043
Grp_2	Grp_1	-23.71400 *	2.28273	.000	-30.2003	-17.2277
	Grp_3	-9.01700 *	2.28273	.002	-15.5033	-2.5307
	Grp_4	-19.20300 *	2.28273	.000	-25.6893	-12.7167
	Grp_5	-20.89600 *	2.28273	.000	-27.3823	-14.4097
Grp_3	Grp_1	-14.69700 *	2.28273	.000	-21.1833	-8.2107
	Grp_2	9.01700 *	2.28273	.002	2.5307	15.5033
	Grp_4	-10.18600 *	2.28273	.000	-16.6723	-3.6997
	Grp_5	-11.87900 *	2.28273	.000	-18.3653	-5.3927
Grp_4	Grp_1	-4.51100	2.28273	.294	-10.9973	1.9753
	Grp_2	19.20300 *	2.28273	.000	12.7167	25.6893
	Grp_3	10.18600 *	2.28273	.000	3.6997	16.6723
	Grp_5	-1.69300	2.28273	.945	-8.1793	4.7933
Grp_5	Grp_1	-2.81800	2.28273	.731	-9.3043	3.6683
	Grp_2	20.89600 *	2.28273	.000	14.4097	27.3823
	Grp_3	11.87900 *	2.28273	.000	5.3927	18.3653
	Grp_4	1.69300	2.28273	.945	-4.7933	8.1793

***** The mean difference is significant at the .05 level.

Table 6: Type of failures

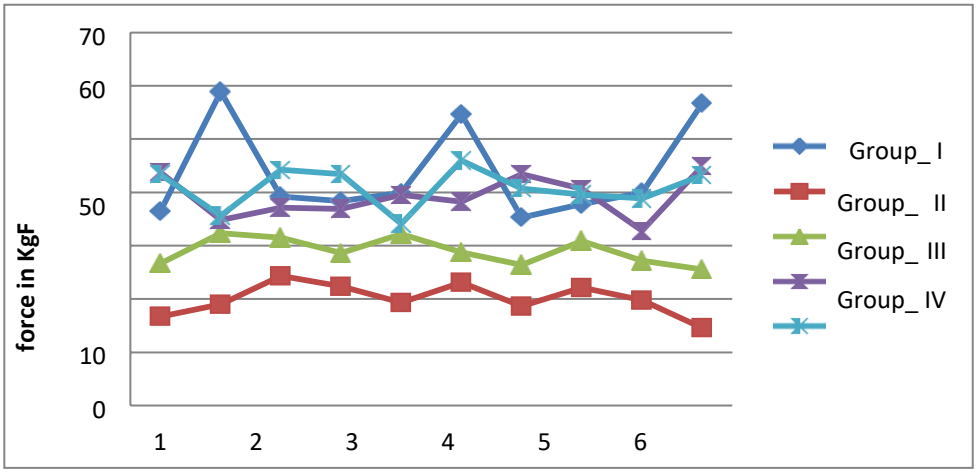
Sample No.	Group II	Group III	Group IV	Group V
1	A	A	C	C
2	M	C	M	A
3	A	C	A	A
4	A	M	C	A

5	A	A	A	C
6	C	A	M	M
7	A	C	A	C
8	A	A	A	A
9	A	A	M	A
10	A	M	M	A

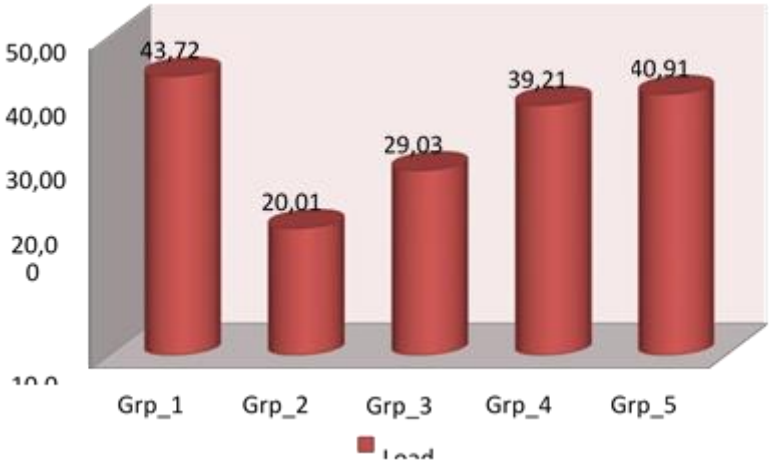
Table 7: Type of failures (%) in 4 groups.

	Group II	Group III	Group IV	Group V
Adhesive (A)	80 %	50 %	40 %	60 %
Cohesive (C)	10 %	30 %	20 %	30 %
Mixed (M)	10 %	20 %	40 %	10 %

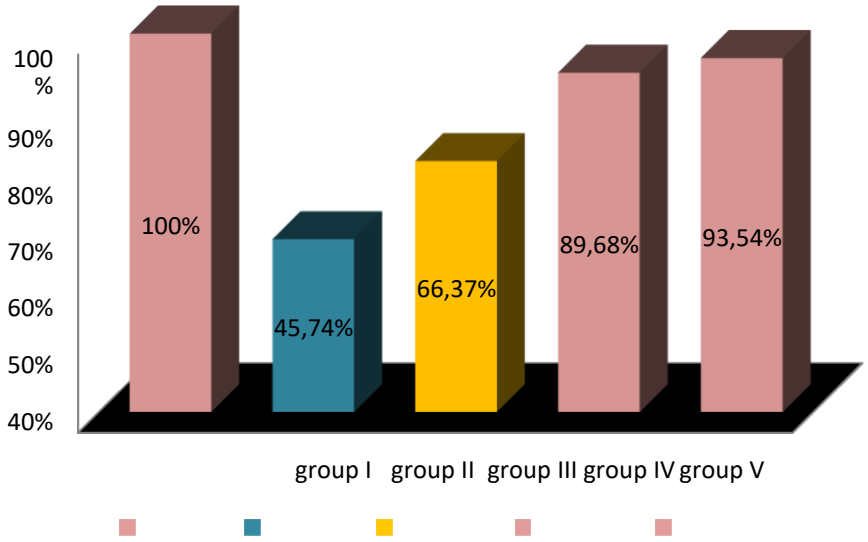
Graph 1: Force required to fracture each sample in the 5 groups



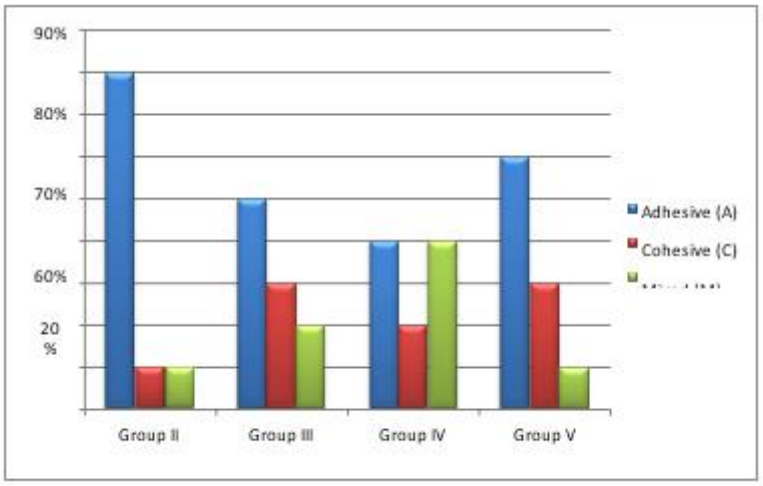
Graph 2: Comparison of mean forces required to fracture the samples in the 5 groups.



Graph 3: Fracture resistance of various groups compared to group 1: (Different shades = statistically significant)



Graph 4: Type of failures (%) in 4 groups.



Discussion

The major objective of restorative dentistry is to restore teeth in a way that allows conservation of healthy dental tissues, esthetics, function, and durability. The ideal treatment would be to attain restorations that are almost as strong as the natural teeth themselves and as well as esthetically pleasing. Fractured anterior tooth is one such clinical situation which is highly challenging for a clinician.

The development of adhesive materials has provided new perspectives in the treatment of fractured anterior teeth. The re-attachment of the fractured fragment is a simple and low- cost method, which has the potential of providing better and long- lasting esthetics, increased wear resistance and thus improved function. However, re-attachment is only possible when the fragment is recovered after the trauma, and the fragment is intact with a good adaptation to the remaining tooth.[15]

Generally, the resistance to fracture of the reattached teeth will not be the same as the intact teeth. However, depending on the restorative technique and the material used, the resistance to fracture could be similar to non-fractured teeth. There is no agreement in the literature about the best technique to reattach the fragments and mostly the choice isempirical. [15]

With the advent of new systems of dentinal bonding and the developments in adhesive dentistry, a composite build-up restoration is, without a doubt, the treatment of choice whenever the fractured fragment is no longer available. The incremental technique, through the application of successive layers of resin, yields a restoration opaquer in the dentinalregion and more translucent in the region of the incisor margin. It is capable of restoring a natural translucence, shape and texture to thetraumatizedtooth.[10] When restoring traumatized anterior tooth, the extension of the fracture

in a gingival direction, the loss of the tooth structure, the existence of endodontic treatment, and the availability and possibility of utilizing the tooth fragment influence the clinician's ability to incorporate minimally adhesive protocols. The quality of the remaining dental structure, occlusion, and the patient's esthetic demands further impact treatment selection.[16]

Particularly in children, other factors must be taken into account when choosing a treatment for maxillary incisor coronal fractures. It is important to remember that the pulp chambers are occupying a greater volume and the fracture exposes a large number of open dentinal tubules to the oral environment, thus providing direct communication to the pulp. Moreover, the teeth are neither totally erupted nor in their final position. Additionally, right after the injury, the traumatized tooth should be managed with a minimal amount of manipulation to avoid more damage to the pulp or periodontium. [16]

Anterior teeth usually fracture in a manner that is unfavorable to re- attachment. 80% of the traumatized incisors fracture obliquely in an apical direction from labial to lingual. Stokes and Hood (1993)[17]confirmed this tendency in the laboratory with mid-facial pendulum impact. Dean et al. (1986) [17] have shown this fracture orientation to be the least resistant to labially applied forces after re-attachment, such as would occur with repeated orofacial trauma.

Human teeth were selected in this study as there appeared to be a trend for higher bond strength values with bovine than with human teeth. [18] A study by Farik et al., showed higher impact strength values with bovine teeth which was due to larger size and thickness, with greater surface area. [19]

In this study, incisal fragments were obtained by sectioning the proximo- incisal part with a thin diamond saw. Loguercio et al, (2004) [20] obtained different results when the teeth were fractured rather than cut with a thin diamond saw. When sectioning with a diamond saw, the reattachment techniques showed similar performance. Most techniques presented a fracture strength recovery of approximately 60%. However, different fracture strengths were observed among the techniques when fractured instead of sectioned. Methods that promote tooth fracture are more realistic since they maintain precise fit between the remnant and the fragment which have most uncomplicated crown fractures than other technique. On the other hand, sectioning represents cases where the loss of structure was enough to avoid a precise fit between the parts.[20] Sectioning methods reduces the variation in resistance to fracture resulting from the thickness of the layers of enamel and dentin present. The anatomy of the surface produced by the cut is different from the surface resulting from the fracture. With the sectioning method, a smear layer is produced that is not found on the fractured surface. A fractured surface tends to be parallel to the direction of the enamel prisms, while the orientation of the surface exposed by cutting is dictated by the direction of the cut. The choice of sectioning was also dictated by the fact that the cut establishes a repeatable condition absolutely necessary for an in vitro study, although it does not exactly simulate an accidental fracture.[10]In Group II and Group III, prior to reattachment an internal dentinal groove was prepared within the fragment and the remaining tooth. Many techniques have been proposed for reattaching the fragment to the remaining tooth: using a circumferential bevel before reattaching (Simonsen, 1979; Amir, Bar- Gil and Sarnat, 1986; Burke, 1991; Walker, 1996), placing a chamfer at the fracture line after bonding (Davis, Roth, and Levi, 1983; Franco and others, 1985; Andreasen and others, 1995), using a V-shaped enamel notch (Simonsen,1982), placing an internal groove (Baratieri and others, 1994; Walker, 1996) or a superficial over contour over the fracture line (Reis and others, 2001). Some authors have also indicated bonding with no additional preparation (Osborne and Lambert, 1985; Martens and others, 1988; Dickerson, 1994).[11]

Many studies have concluded that placement of internal dentinal groove may provide higher esthetic durability as well as excellent fracture strength of the restoration.[5,21] It also provides a greater adhesion area and act as an internal resin bar, which acts as an opponent to the compression load applied on the buccal surface and provides greater resistance to fracture. Also, this technique did not alter the fit between the fragment and the remaining tooth. [5] A Reis et al., (2001) [5] concluded that the placement of an internal dentinal groove can provide fracture strength equal to that found in sound teeth and bonding with no additional preparation and placement of a chamfer are not indicated due to the low fracture strength obtained. Esin Pusman et al., (2010) [21] concluded that the highest fracture strength recovery was obtained using internal dentinal groove technique followed by the over contour and simple reattachment technique.

Many studies have been performed in the past relating to the materials used to reattach the fragments. Using bonding agents only (Munksgaard and others, 1991; Andreasen and others, 1993; Badami, Dunne and Scheer, 1995; Kanca, 1996; Pagliarini and others, 2000), associating bonding agents with flowable resins (Small, 1996; Farik and Munksgaard, 1999; Farik, Munksgaard and Andreasen, 2000), dual or self-cured luting cements (Dickerson, 1994; Reis and others, 2001) or light cured luting cements (Dean, Avery and Swartz, 1986) have been extensively reported. Associating bonding agents with hybrid or microfill resin composites has also been used by others (Simonsen, 1982; Martens and others, 1988; Burke, 1991; Diangelis and Jungbluth, 1992; Baratieri and others, 1994).[11]

In terms of retention, the clinical outcome of the restorations utilizing tooth fragments is primarily dependent on strong and durable enamel bonding. In spite of the ever-increasing popularity of self- etching bonding agents, adhesive systems that utilize phosphoric acid as a separate conditioner still represent the gold standard of reliable and strong enamel bonding. [21] Farik et al (2000) [22] gave hypothesis that total- etch, one- bottle dental bonding agents are a combination of the primer and adhesive in the same bottle, and the amount of resin present in these adhesive systems may not be sufficient to ensure an appropriate bonding when used for reattachment purpose. [15] Pagliarini et al (2000)[23] have advised that for reattachment of fractured tooth fragments, multiple- step adhesives may guarantee a bonding force stronger than one- bottle adhesives i.e. fourth- generation adhesives and can guarantee a bonding force stronger than fifth- generation adhesives because of the higher resin content in such adhesive systems.[15] Accordingly, a multi-step fourth generation adhesive system, ScotchBond Multipurpose was used in this study for re-attachment of the fragments.

Along with composition of the adhesive system, the technique for its application is also important. As differences, for example, in the wetting of dental substrate could impair the adhesive properties. Thus, it is important to follow the manufacturer's instructions, which was performed in this study, using the adhesive systems with moist dentin.[15]

Andreasen et al (1993) [24] concluded that materials with relatively high mechanical properties (flexural strength and flexural modulus), such as resins, should be used in conjunction with adhesive systems instead of single application in order to withstand functional stresses.[5] A. Reis et al., (2002)[11] concluded that along with the technique used to bond the fragment to the fractured tooth, the kind of material or its association plays an important role in the fracture strength of fragment bonded teeth. By merely varying the kind of adhesive systems used, different fracture strength recoveries can be obtained (Badami[25]and others, 1995; Pagliarini [23] and others, 2000). In this study, a dual- cure resin system and a micro- hybrid composite resin has been used along with adhesive system in two different groups.

Many studies have used dual- cure resin cement for the re-attachment procedure.[11, 15] It is well documented that the light intensity decreases when light activation is performed through dental tissues (Losche, 1999; Reis et al, 2004 [26]). Demarco et al., 1998 [15] verified that dual- cure systems had a tendency to exhibit better bond strengths over time than the light- cure systems (7 days). Thus, concerns about the possible detrimental effects on the degree of conversion of the resin cement led to choose dual version of resin cement in this study. A light- curing micro- hybrid resin composite has been used in many studies for reattaching the fractured fragment to the tooth and a higher fracture resistance was obtained.[5,15,20,21]The filler content of this heavy- filled composite provides better mechanical properties thus could better reinforce the reattachment interface. [24] The high toughness of resin composite is likely to be responsible for absorbing the load used to fracture the restored tooth.[5]

Composite build- up is the most popular way to restore a fractured tooth when the fragment is not available.[5] Direct composite restorations are an extremely conservative procedure and can be performed in a relatively short time with good aesthetics and mechanical results and also its abrasiveness is lower towards opposing teeth[27]. According to Andreasen and others (1995), survival time is similar in both treatments (re-attachment technique and composite build-up).[5]

A 45^0 bevel was given in Group IV and V before composite build- up as the beveling process is essential and very important in terms of esthetics and adhesion of composite restoration of fractured anterior teeth. Beveling increases the surface area and causes a more efficient adhesion. [12] Resin composite build- up has been used as a technique of restoration of fractured anterior teeth in many studies and a high fracture resistance comparable to intact teeth has been obtained.[5,11,20,28] Accordingly, a micro-hybrid and a nano- hybrid composite resin was used in this study for composite build- up in Group IV and Group V.

During the 70's and 80's the main reasons of failure of composite restorations were insufficient wear resistance, loss of anatomic form and proximal contacts, and degradation of the restoration. The improvement in filler technology resulted in more resistant composites and changed the reasons of failure and restoration replacement. For resin-based composites mechanical properties are mainly dependent upon their microstructure and composition. The microstructural characteristics involve the distribution of filler particles in the bulk, the morphology of these filler particles and the presence of pre-existing cracks and voids. These characteristics are directly related to the composition of the composite. Asmussen, Peutzfeldt (1998) observed that the variation of the BisGMA/TEGDMA/UEDMA ratio affected significantly the mechanical properties of the composite, suggesting that specific combinations should be developed according to the specific applications of the material. The long-term durability, evaluated by means of water sorption and solubility of the composites, has also been shown as depending on their organic content.[29]

However, the inorganic filler content is to be considered the most valuable factor concerning the improvement of the mechanical properties of resin-based composites. Kim et al. (2002) observed a significant influence of the filler rate and morphology on the flexural strength and modulus, microhardness and fracture toughness of the composites evaluated. Also, Yap, Teoh (2003), comparing different categories of composites, observed that the microfine composite, with the lowest filler content (40% in volume), presented the lowest flexural properties (strength and modulus).[29] Other factors besides the filler content, such as degree of conversion and type of monomer, could also influence the mechanical behavior of composites. In fact, the morphological aspect of the filler determines its percentage, the silane content and the microstructural characteristics of the composite. The incorporation of nanometric sized filler particles in hybrid composites and even the introduction of exclusively nano- filled composites have been considered the most recent advances in filler technology. Characteristically, these filler particles, due to their considerably small size and rounded shape, expose a high surface area and require, as a consequence, a higher amount of silane. Musanje, Ferracane (2004) [29] found that the incorporation of salinized nanofiller particles significantly increased abrasion and attrition wear resistance of hybrid composite. [29]

The cross- head speed can effectively influence the bonding of fractured teeth. Lower fracture strength will be produced at 500 mm/ min than at 1 mm/ min. [15] Some in vitro studies have employed cross- head speeds ranging from 0.5 to 1.0mm/min [25] Andreasen et al., investigated the effect of loading fragments at 1, 5, 50, 100 and 500 mm/ min and noted that fracture strength decreased exponentially with loading speed. [24] This is in agreement with the clinical observation that rebonded fractured incisors fail if rapid loading is applied while the relatively slow loading applied during mastication does not normally induce failure. [24] A cross- head speed of 1 mm/ min was used in this study which did not simulate the clinicalcondition,but this cross-head speed isusually employed in similar tests. [10,11,20,30]

The results obtained with Group II (Reattachment of fractured fragment with dual- cure resin cement with an internal dentinal groove preparation) showed that the mean force required to fracture the restored teeth was 20.00 ± 3.01KgF which was only 45.74 % of the Group I (intact teeth). This indicates restoration of fractured fragments by reattaching with dual- cure resin cement does not attain even one half of the fracture resistance of control intact teeth. The statistical comparison of group II with groups I, III, IV and V showed highly statistically significant difference ($P < 0.05$).

These results are comparable with:

Demarco FF, Fay R-M, Pinzon LM (2004)[15] investigated the fracture resistance of reattached coronal fragments of seventy- two bovine incisors using different materials and tooth preparations. For bonding conditions tested, the dual- cured resin cement (RelyX ARC) produced lower failure loads than with the resin composite. Fracture resistance of about 25% and 16% compared to control teeth was obtained with dual- cure resin cement in beveled and non- beveled group respectively.

A Reis, A Kraul, C Francci (2002) [11] compared the fracture strength of two different techniques (bonded only and buccal chamfer) and different material combinations used to reattach tooth fragments using one hundred and eighty sound human lower incisors. Fracture resistance recovery obtained in dual- cure resin cement was 36.6% and 69.8% with bonded only and chamfer groups respectively.

Shortcomings of using dual- cure resin cement are [11]:

1) The amine accelerator necessary for dual polymerization can cause the color of the luting agent to change over time (Rosenstiel, Land & Crispin, 1998)[11].

2) Schiltz & others, (2000) [11] used dual-cured resin cement on simplified-step adhesive systems showed that shear bond strength of the tested assembly was inversely related to the time interval between placement of the dual-cured resin cement and light-activation

3) Furthermore, using dual- cured resin cement presents some inconvenience to the clinical procedure: it requires mixing two pastes that lead to air incorporation and is more time-consuming.

The results obtained with Group III (Reattachment of fractured fragment using micro-hybrid composite with an internal dentinal groove preparation) showed that the mean force required to fracture the restored teeth with this method was 29.02 ± 2.55 KgF which was 66.37% of the Group I (intact teeth). This indicates restoration of fractured fragments by reattaching with micro-hybrid composite attains more than half of the fracture resistance of control intact teeth. The statistical comparison of group III with groups I, II, IV and V showed highly statistically significant difference ($P < 0.05$).

These results are comparable with:

A Reis, C Francci, AD Loguercio (2001) [5] compared the fracture strength of sound and restored teeth using a micro- hybrid resin composite (Aelitefil, BISCO) and four reattachment techniques. Fracture resistance of the group restored with micro- hybrid composite resin with internal dentinal groove 21.94

± 3.92 KgF. The fracture strength achieved was more than half as compared to control intact teeth.

Esin Pusman et al. (2010) [21] evaluated and compared the bond strengths of experimentally fractured three hundred and twenty human mandibular incisors tooth fragments reattached with different adhesive materials and retentive techniques. The highest fracture strength recovery was obtained with the group using light- cured micro-hybrid composite using the internal dentin groove technique 54 ± 0.58%, which is more than half of the fracture strength value of control intact teeth.

These results are not in accordance with:

Demarco FF, Fay R-M, Pinzon LM (2004)[15] investigated the fracture resistance of reattached coronal fragments of seventy- two bovine incisors using different materials and tooth preparations. For bonding conditions tested,

the light- cured micro- hybrid composite resin attained fracture resistance of only 29% and 20% compared to control teeth in beveled and non- beveled groups respectively.

The difference in the results obtained could be due to:

Bovine incisors were used instead of human teeth as used in the present study. Thermocycling procedure was not performed after the reattachment of the samples. Samples were divided into beveled and non- beveled groups as reattachment techniques where as in present study an internal dentinal groove was prepared. A cross-head speed of 0.6 mm min^{-1} was used where as a cross-head speed of 1 mm min^{-1} was used in the present study.

Results of Group IV and Group V:

Group IV (Composite build- up of fractured teeth with micro-hybrid composite with an enamel bevel preparation) showed the mean force required to fracture the restored teeth with was 39.21 ± 4.00 KgF which was 89.68 % of group I (Intact teeth).

Group V (Composite build- up of fractured teeth with nano-hybrid composite with an enamel bevel preparation) showed the mean force required to fracture the restored teeth was 40.90 ± 3.86 KgF which was 93.54 % of the group I (Intact teeth).

This indicates restoration of fractured fragments by composite build- up technique using micro- hybrid and nano-hybrid composite attains a high fracture resistance which is very close to that of control intact teeth. The statistical comparison of group IV and V with groups II and III showed highly statistically significant difference ($P < 0.05$) and with group I showed no statistically significant difference ($P > 0.05$).

These results are comparable with:

A Reis, C Francci, AD Loguercio (2001) [5] compared the fracture strength of sound and restored teeth using a resin composite (Aelitefil, BISCO) and four reattachment techniques. Fracture resistance of teeth restored with composite build- up (micro- hybrid) was 25.02 ± 9.68 KgF which was 95.8% of the control intact teeth.

AD Loguercio, J Mengarda, R Amaral, A Kraul, A Reis (2004) [20] evaluated the effect of fractured or sectioned fragments on the fracture strength recovery of four techniques used for reattachment and resin composite build-up in eighty human lower central incisors. Fracture strength of teeth restored with resin composite(micro-hybrid) after sectioning was obtained as 22.2 ± 3.5 KgF which was equal to that of control intact teeth.

The difference in the values obtained in both studies could be due to: Mandibular incisors were used instead of maxillary incisors as used in the present study. The methodology to obtain the fractured fragment was direct fracturing of the samples with Universal Testing Machine instead of sectioning which was used in the present study. Thermocycling procedure was not performed after the restoration of the samples.

These results are not in accordance with:

A. Sengun, F. Ozer, N. Unlu & B. Ozturk (2003) [31] investigated the shear bond strengths of sectioned 70 human mandibular incisor edge fragments reattached using luting cements, bonding agents or restored with composite resins. Shear bond strengths obtained with two of the composite resin build- up groups were 7.48 ± 3.60 MPa (Clearfill SE Bond + Clearfil AP- X composite resin) and 6.60 ± 3.26 MPa (Single Bond + 3M Silux composite resin) which was almost half the shear strength obtained with intact teeth (13.40 ± 2.75MPa).

The differences in the results obtained could be due to:

Human mandibular central and lateral incisors were used instead of maxillary central incisors. Thermocycling procedure was not performed after the reattachment of the samples. Composite build- up was performed without giving a 45^0 bevel prior to restoration.

Several aspects govern the choice of a technique or association of materials for restoring fractured anterior teeth. In the present study, every effort was made to duplicate the oral situations whenever possible; however, the in vivo responses might differ from the present study. Nonetheless, clinical implications of this research project are

significant. The conclusion of this in- vitro investigation must be extrapolated to the clinical situation with care and further in vivo trials with these materials and surface treatments are indicated to confirm the validity of these recommendations.

Conclusions:

Within the limitations of the present study, following conclusions can be drawn:

1. The fracture resistance of none of the restorative techniques used to restore fractured anterior teeth was equal to that of the sound teeth.
2. The fracture resistance of teeth reattached using micro-hybrid composites was higher than with the dual-cure resin cement with a highly significant statistical difference.
3. The fracture resistance of teeth which were restored with nano-hybrid composite build-up was higher than with micro-hybrid composite build-up technique but there was no significant statistical difference among the two techniques.
4. The fracture resistance of teeth restored with two composite build-up techniques was higher than the restoration with two reattachment techniques. Composite buildup provides fracture resistance closer to those in sound teeth and is the most popular way to restore a fractured tooth when the fragment is not available.

Bibliography

1. Emre Ozel, Alper Cildir, Yonca Ozel. Reattachment of anterior tooth fragment using a self- etching adhesive: A case report. J Cont Dent Pract 2008; Vol 9 (1): 1-7.
2. Hamilton FA, Hill FJ, Holloway PJ. An investigation of dento-alveolar trauma and its treatment in an adolescent population. Part 1: The prevalence and incidence of injuries and the extent an adequacy of treatment received. Br Dent J 1997; 182: 91-95.
3. Andreasen JO, Raven JJ. Epidemiology of traumatic dental injuries to primary and permanent teeth in a Danish population sample. Int J Oral Surg 1972; 1: 235-39.
4. Petti S, Tarsitani G. Traumatic injuries to anterior teeth in Italian schoolchildren: prevalence and risk factors. Endod Dent Traumatol 1996; 12: 294-97.
5. Reis. A, Francci C, Loguercio AD, Carrilho MRO, Filho LER. Re-attachment of anterior fractured teeth: Fracture strength using different techniques. Operative Dentistry 2001; 26:287-94
6. Murchison DF, Burke FJT, Worthington RB. Incisal edge reattachment: indications for use and clinical technique. British Dental Journal 1999; 186 (12): 614-9.
7. Yucel Yilmaz, Zehir C, Eyuboglu O, Belduz N. Evaluation of success in the reattachment of coronal fractures. Dent Traumatol 2008; 24: 151-8.
8. Georgia V. Macedo, Patricia I. Diaz, Carlos Augusto De O. Fernandes, André v. Ritter. Reattachment of Anterior Teeth Fragments: A Conservative Approach. J Esthet Restor Dent 2008; 20:5–20.
9. Andreasen FM et al. Bonding of enamel- dentin crown fractures with GLUMA and resin. Endod Dent Traumatol 1986; 2: 277-80.
10. Edoardo Stellini et al. Fracture strength of tooth fragment reattachments with postpone bevel and overcontour reconstruction. Dental Traumatology 2008; 24: 283-88
11. Reis A, Kraul A, Francci C. et al. Re-attachment of anterior fractured teeth: Fracture strength using different materials. Operative Dentistry 2002; 27:621-7.
12. Emre Ozel et al. Two year follow- up of fractured anterior teeth restored with direct composite resin: report of three cases. Dental Traumatology 2008; 24: 589-92.
13. Gustavo M.S. Oliveira, Andre V. Ritter. Composite resin restorations of permanent incisors with crown fractures. Pediatric Dentistry 2009; 31: 102- 116.
14. Gandhi K., Nandlal B. Effect of enamel preparations on fracture resistance of composite resin build up of fractures involving dentin in anterior bovine teeth: An in vitro study. J Indian Soc Pedod Prev Dent 2006; 69-75.

15. Demarco FF, Fay RM, Pinzon LM, Powers JM. Fracture resistance of re- attached coronal fragments–influence of different adhesive materials and bevel preparation. Dental Traumatology 2004; 20:157-63.

16. Sakai VT, Anzai A, Silva SMB, Santos CF, Machado MAAM. Predictable esthetics treatment of fractured anterior teeth: a clinical report. Dent Traumatology 2007; 23: 371-375.

17. Worthington RB, Murchison DF, Vandewalle KS. Incisal edge reattachment: The effect of preparation utilization and design. Quintessence International 1999; 30 (9):637-42.

18. C. S. Fowler, M. L. Swartz, B. K. Moore, B. F. Rhodes. Influence of selected variables on adhesion testing. Dent Mater 1992; 8: 265-269.

19. AR Prabhakar, AJ Kurthukoti, G Kayalvizhi. A comparision of impact strength of fragment bonded anterior teeth using three different restorative materials: An in vitro study. J Indian Soc Pedod Prev Dent 2007; 25

20. Loguercio AD, Mengarda J, Amara lR, Kraul A, Reis A. Effect of fracture or sectioned fragments on the fracture strength of different reattachment techniques. Operative dentistry 2004; 29 (30):292-300.

21. Esin Pusman, Zafer C. Cehreli, Nil Altay, Bahtiyar Unver. Fracture resistance of tooth fragment reattachment: effects of different preparation techniques and adhesive materials. Dental Traumatology 2010; 26: 9-15.

22. Farik B, Munksgaard EC, Andreasen JO. Impact strength of teeth restored by fragment- bonding. Endodontics and Dental Traumatology 2000;16

23. Pagliarini A, Rubini R, Rea M, Campese M. Crown fractures: Effectiveness of current enamel-dentin adhesives in reattachment of fractured fragments. Quintessence International 2000; 31(2):133-6.

24. Andreasen FM, Steinhardt U, Bille M, Munksgaard EC. Bonding of enamel-dentin crown fragments after crown fracture. An experimental study using bonding agents. Endodontics and Dental Traumatology 1993; 9:111-4

25. Badami AA, Dunne SM, Scheer B. An in vitro investigation into the shear bond strengths of two dentin-bonding agents used in the reattachment of incisal edge fragments. Endo and Dent Traumatol 1995; 11:129-35.

26. A Reis, AD Loguercio, A Kraul, E Matson. Reattachment of fractured teeth: A review of literature regarding techniques and materials. Operative dentistry 2004; 29 (2): 226-233.

27. G. P. M. Brambilla Milan, E. Cavalle Monza. Fractured incisors: a judicious restorative approach- part 1. Inter Dent J 2007; 57: 13-18

28. Masoud Fallahinejad Ghajari, Roshan Roshennajad and Amir Ghasemi.Microtensile bond strength of fragment reattachment vs. resin composite restoration in crown fractures. Research Journal of Biological sciences 2007; 2 (6): 682-686.

29. Sinval Adalberto Rodrigues Junior, Cesar Henrique Zanchi. Flexural strength and modulus of elasticity of different types of resin- based composites. Brazilian Oral Research 2007; 21 (1):2-14.

30. Sufyan K. Garoushi, Ahmed M. Ballo. Fracture resistance of fragmented incisal edges restored with fiber- reinforced composite. J Adhes Dent 2006; 8: 91-95.

31. A. Sengun, F. Ozer, N. Unlu & B. Ozturk. Shear bond strengths of tooth fragments reattached or restored. J of Oral Rehab 2003; 30: 82-86.