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BOND STRENGTH EVALUATION OF VARIOUS PULP CAPPING MATERIALS TO VARIOUS RESIN BASED RESTORATIONS UTILIZING DIFFERENT ADHESION APPROACHES

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ABSTRACT

Aim: compare shear bond strength SBS between various pulp capping materials ; light cured cavity base and liner(Base.it®), Dycal ®and MTA Plus® and various resin based restoration used as bases; flowable resin composite (Tetric N-flow®) and resin modified glass ionomer cement (Riva LC®) utilizing two different adhesion approaches.

Materials and Methods: 180 acrylic molds were utilized, in which holes with 4 diameter and 2 mm depth created in each. Then, the samples were divided randomly to three main groups depends on pulp capping materials, namely; light cured Calcium hydroxyapatite oligomer (Base.it®) (Spident USA, Inc.), self- curable calcium hydroxide (Dycal®) ;(Dentsply USA, Sirona) and self-curable mineral trioxides aggregates (MTA plus®) (Avalon Biomed Inc .Bradenton, FL, USA);(n = 60) of each. Each tested group was further subdivided to two subgroups depends on the tested restorative materials, flowable resin composite (Tetric N-flow®)Vivadent Ivoclar, Inc., Amherst, N.Y., USA,and resin modified glass ionomer RMGIC (Riva LC®) SDI, Victoria, Australia, (n = 30). Each subgroup was further divided into two subgroups according to adhesion strategy of surface treatment, etch and rinse ER and self-etch SE (n=15), with Tetric N bond® (Vivadent Ivoclar, Inc., Amherst, N.Y., USA.). All the used capping materials was leveled using a mixing spatula to be flush with the surface of the block and covered with celluloid strips and small glass slide to ensure standardization. Then, the surface of each material treated with the different adhesive approaches. Then the different tested restorative materials injected into transparent polyethylene tube of 3 mm internal diameter and 2 mm in hieght, the SBS test carried out by mounting the specimens on the Hounsfield Universal testing machine at which the cross head speed was 1 mm/min. The SBS was calculated and were expressed in MPa. All fractured deboned surface samples were examined by Stereomicroscope. Three-way ANOVA followed by Tukey's post hoc test carried out.

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Result: A significant interaction between tested variables. Light cured Calcium hydroxyapatite oligomer (Base.it®) had the upmost SBS values followed by the self- curable mineral trioxides aggregates (MTA plus®) while the lowest values found with self- curable calcium hydroxide (Dycal®). A significantly higher bond strength values achieved with ER in both tested restorative materials; ($p<0.001$).

Conclusion: The adhesion strategy used influences the SBS of the tested capping materials. As light cured Calcium hydroxyapatite oligomer (Base.it®) had the highest SBS followed by self-curable mineral trioxides aggregates (MTA plus®). The capping material to be used should be bioceramic in nature to ensure successful treatment.

KEYWORD: MTA Plus, Base .it, Dycal, bond strength.

INTRODUCTION

Vital pulp therapy (VPT) is a biologic and conservative therapeutic approach that is used to maintain the vitality status and health of the pulpal tissue after the occurrence of the caries or the traumatic exposures. [1,2] It encompasses two major therapeutic approaches: indirect pulp therapy for deep caries, a direct pulp capping in cases of pulp exposure. [3,4] Biomaterials indicated for use in VPT should be biocompatible, have the capability to maintain pulp vitality, adherence to dentine as well as to the restorative material, and withstand stresses during placement and function.

The superior biocompatibility, antimicrobial property, and bioactivity in terms of hard tissue barrier formation, are the main reasons that makes calcium-based materials widely employed for pulp capping material. [5] The self-curable Calcium-based substance was soluble and lacking inherent adhesive qualities, resulting in pulp treatment failure. [6] However, the benefit of the light curable calcium-based pulp capping materials empower its application to improve the VPT scenario. Light curable calcium-based materials were projected to improve VPT success by providing improved adhesive properties as well as the therapeutic effects of calcium in pulpal repair.

The high compatible physical and biochemical features of various calcium silicate-based materials have advocated for the effective VPT outcomes in modern dental practice. MTA plus is one among them, and it is mostly composed of calcium hydroxide and calcium silicate. Being MTA-based formula, it is an excellent alternative for pulp capping. MTA enhances proliferation, migration, and differentiation of the odontoblast-like cells that can produce a collagen matrix by inducing cytologic in addition to functional changes within pulpal cells, which result in the formation of fibro dentine altogether with reparative dentin at the surface of mechanically exposed dental pulp. This mineralized matrix was generated initially by osteodentin followed by tertiary dentin production. [7]

The adhesive compatibility with different adhesion strategies (ER and SE) in means of shear bond strength (SBS) of the different pulp capping material to overlying restoration is another critical factor which determines the success of VPT. [8] Flowable resin composites materials and resin modified glass ionomer cement (RMGIC) make a preferred selection of materials to produce a monolithic reconstruction and create a microleakage and voids-free restoration, they are well proved to exhibit superior adaptation than the conventional packable composite and lesser moisture sensitivity than conventional glass ionomer cements.[2] Because a restoration after pulp capping operations is critical for their success, Concerns have been raised about the bond strength evaluation of restorative materials to the pulp capping materials.

Therefore, we conducted this in vitro study to assess and compare the SBS of three different

calcium-enriched mixtures of the pulp capping materials; light cure Calcium hydroxyapatite oligomer (Base.it®), self-curable calcium hydroxide (Dycal®) and self- curable mineral trioxides aggregates (MTA plus®) to flowable resin composites ; Tetric N–flow® (Vivadent Ivoclar, Inc., Amherst, N.Y., USA) and Riva LC® resin modified glass ionomer RMGIC (SDI, Victoria, Australia) and (RMGIC) utilizing two adhesion approaches; ER and SE).

The null hypothesis of the current study stating that "there is no difference in the SBS value of the tested pulp capping agents and overlaying restorative materials using different adhesion strategies". The objective of the study was to find an appropriate pulp capping agent as well as restorative material to improve the success outcome of VPT.

MATERIALS AND METHODS:

Sample size and specimen preparation:

A power analysis was developed to have enough power to apply a statistical test of the null hypothesis that no difference in shear bond strength would be discovered between each tested group. The least required sample size (n) was arbitrated to be (60), by using an alpha (α) level of (0.05), a beta (β) level of (0.05) (i.e. power=95%), and an effect size (f) of (0.75) estimated according to the results of a prior study [8]. G*Power version 3.1.9.7 * was used to compute the sample size. [9]

A total of 180 cylindrical acrylic molds were used. Holes with 4mm diameter and 2 mm in depth created in each acrylic mold. Each featuring three round spaces, to accommodate three applications of the capping materials overlayed by the tested restorative materials. Then divided into three main groups according to pulp capping materials used in this study, Base. It ® light cured cavity base and liner (Spident USA, Inc.), Dycal ® (Dentsply USA, Sirona) and MTAplus ® (Avalon Biomed Inc .Bradenton, FL, USA) (n = 60). Each main group was then subdivided to two subgroups according to restorative materials used, flowable resin composite material ;Tetric N–flow® (Vivadent Ivoclar, Inc., Amherst, N.Y., USA) and Riva LC® resin modified glass ionomer cement RMGIC (SDI, Victoria, Australia), (n = 30). Each group will be further subdivided into two subgroups according to adhesion strategy of surface treatment approach, self -etch and etch and rinse (n=15). Capping materials that were in use in the study illustrated in the table 1.

Shear bond strength test:

In group of Base.it light cured cavity base and liner (ready injectable syringe), the material was injected inside the holes, leveled with spatula and covered with celluloid strips, and small glass slide was placed on the top of the molds so that all the used materials set against a smooth surface to confirm standardization of the sample surface. Then the material was light cured using a LED polymerization unit (Ivoclar Vivadent Inc., Amherst, N.Y., USA) of 800mW/cm2 for 20 seconds according to manufacture instructions. In the first subgroup, material surfaces treated for 15 seconds with 35% of the phosphoric acid gel (3M ESPE, St Paul, MN, USA), washed for 30 seconds, and then dried. Then, Universal adhesive Tetric N bond® (Vivadent Ivoclar, Inc., Amherst, N.Y., USA.) was applied and then light cured following the manufacturer instructions;(single coat, applied by small brush with agitation for 15 sec, gentle dryness by oil free air spray for 5 sec for solvent evaporation and cured for 10 seconds . Transparent polyethylene tube of 3 mm internal diameter and 2 mm height, then was applied on a ready prepared specimen. Fixing was done before adhesive curing. The tubes were filled with flowable resin composite

* Faul, Franz, et al. "G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences." *Behavior research methods* 39.2 (2007): 175-191.

TABLE (1) Capping materials composition:

The product	Composition	Manufacture	lot number
Base.it	-Calcium hydroxyapatite in urethane methacrylate oligomer- calcium ions- hydroxy ions-phosphate ions.	Spident USA,Inc.	B121023
Dycal	-Two-paste calcium hydroxide system:1) a base containing titanium dioxide in a glycolsalicylate and 2) a catalyst containing calcium hydroxide and zinc oxide in ethyl toluensulfon- amide.	Dentsply,Caulk Sirona, USA	023304
MTA plus	Powder(50% smaller than MTA and <1μm) and gel system consisting of an extremely fine, inorganic powder of Tricalcium and Dicalcium Silicate Powder consists of mixture of calcium oxide, silicon oxide, bismuth oxide. And gel which is hydrated polymer gel	Avalon Biomed Inc .Bradenton, FL, USA)	PK21222486

Tetric N-Flow® then light cured for 10 sec as well as readymade capsules of RMGIC Riva LC ®, were triturated for 7 seconds, injected and light-cured for 40 seconds. The same procedures were followed in the Base.it® light cured cavity base and liner second subgroup in SE strategy without acid etching.

In group of Dycal®, separate equal amount of base and catalyst were mixed on a paper pad using metal spatula according to manufacture instruction and the mixture placed inside the molds with the spatula to be leveled inside each hole of the mold and pressed against glass slab to avoid any material voids, the rest of the bonding steps and insertion of the restorations were the same as described for Base.it® subgroups.

In group of MTA plus®, MTA Plus is a specialized cement consists of Di and Tri-Calcium Silicate compounds, derivational from advanced material research in the inorganic hydraulic powder technology. One scoop of powder was dispensed on non-absorbable pad with one drop of gel, and the mix was gradually stirred to hydrate the powder with gel till the putty consistency is obtained according to the manufacture instruction. The mix was applied to the well; material was collected by the aid of metal spatula , then applied by plastic instrument followed by gentle pressure of hand plugger with paper pad to ensure complete filling of each well. The rest of the bonding steps and insertion of the restorations were the same as described for Base.it ® and Dycal ® subgroups.

The samples were tested for macro shear bond strength by mounting them on Hounsfield Universal testing machine (Instron, USA). The shear bond strength was calculated and expressed in MPa. The specimens were mounted in the Instron testing machine (model no.8500, Illinois Tool Works Inc., Norwood, MA, USA) with the crosshead perpendicular and flush with the restoration interface and the sealer material. The specimens were loaded at a 1 mm/min crosshead speed using a knife-edge blade.

Stereomicroscope evaluation:

All fractured de-bonded surface of the samples were then inspected at 40× magnification. Stereomicroscope (Olympus SZX16, Olympus, Tokyo, Japan.) to address the failure modes. The failure modes were categorized as adhesive (failure at the resin-experimental materials and capping materials interface), cohesive (failure inside the experimental materials) and mixed failure including restorative material, adhesive layer and capping material.

Statistical analysis:

Numerical data was calculated as mean with 95% confidence intervals, standard deviation (SD), minimum and maximum values. Shapiro-Wilk's test was used to the test for normality and Homogeneity of variances was tested using Levene's test. Data showed parametric distribution and variance homogeneity and were analyzed using three-way ANOVA followed by Tukey's post hoc test. Comparison of simple main effects was done utilizing the error term of the three-way model with p-values adjustment using Bonferroni correction. Effect sizes were analyzed based on Cohen (1988)*.[10] The significance level was set at $p<0.05$ within all used tests. Statistical analysis was performed with R statistical analysis software version 4.3.0 for Windows. [11].

RESULTS

Descriptive statistics for shear bond strength values are displayed in figure (1). Results of three-way ANOVA are presented in table (2). Results indicated a significant three-way interaction between the three experiment variables ($p<0.001$). Simple two-way interactions were statistically significant within Tetric N- Flow®, MTA plus® and both conditioning protocols ($p<0.001$).

Within Riva LC® samples, Base. it® had the highest bond strength values followed by MTA plus® while the lowest values were found with Dycal® and all pairwise comparisons were statistically calculated with significance ($p<0.001$). In addition, a significantly superior bond strength values were achieved in etch and rinse conditioning subgroups ($p<0.001$).

Within samples capped with Base. it®, higher bond strength values were achieved with Tetric N Flow® ($p<0.001$), while the effect of conditioning system was with no statistically significance ($p=0.389$).

Within Dycal® samples, the effects of both restorative material ($p=0.265$) and conditioning system ($p=0.891$) were not statistically significant.

Simple effects comparison within Tetric N-Flow®are presented in table (3) and in figures (2) and (3). Within MTA plus®, etch and rinse significantly increased bond strength ($p<0.001$). While for other capping materials the effect was not statistically significant ($p=1$). Within etch and rinse, Base. it®had the highest bond values followed by MTA plus® then Dycal® with all pairwise comparisons showed statistically significance ($p<0.001$). Within SE samples, Base.it® had significantly higher bond values than other capping materials ($p<0.001$).

Simple effects comparison within MTA plus® are presented in table (4) and in figures (4) and (5). Within Tetric N-flow®, etch and rinse significantly increased bond strength ($p<0.001$). While for Riva LC® samples, the effect was not statistically significant ($p=0.060$). Within etch and rinse, Tetric N-flow® had significantly superior bond strength than Riva LC® ($p<0.001$), However, for SE, difference was not statistically significant ($p=1$).

Simple effects comparison within etch and rinse and SE are presented in table (5) and in figures (6,7,8 and 9). Within samples capped with Base.it® and MTA plus®, Tetric N-flow® had significantly higher bond strength than Riva LC® ($p<0.001$), but for Dycal®, the difference was not significant ($p=1$). Within both restorative materials, Base. it® had the highest bond values followed by MTA plus® then Dycal® with all pairwise comparisons being statistically significant ($p<0.001$).

Failure modes for Base.it® group showed 70% cohesive n=42 and 30 % mixed n=18, MTA plus® 80% cohesive n=48 and 20 % mixed n= 12 while in Dycal® almost mixed failure mode had been shown up.

* Cohen, J. (1988). Statistical Power Analysis for the Behavioral Sciences (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.

TABLE (2) Three-ANOVA for shear bond strength values

Parameter	*Sum of squares*	*Df*	*Mean square*	*f-value*	*p-value*	*Partial eta squared (95% CI)*
Restorative material	176.42	1	176.42	65.27	**<0.001***	0.280 (0.188:0.364)
Capping material	763.42	2	381.71	141.21	**<0.001***	0.627 (0.552:0.678)
Conditioning	68.75	1	68.75	25.43	**<0.001***	0.131 (0.061:0.211)
Restorative* capping	112.53	2	56.27	20.82	**<0.001***	0.199 (0.110:0.278)
Restorative* conditioning	6.05	1	6.05	2.24	**0.137**	0.013 (0.000:0.055)
Capping* conditioning	106.71	2	53.36	19.74	**<0.001***	0.190 (0.103:0.270)
Restorative* capping* conditioning	49.16	2	24.58	9.09	**<0.001***	0.098 (0.033:0.167)
Error	454.12	168	2.70			

****Significant (p<0.05), eta < 0.02 - Very small, 0.02 <= eta < 0.13 – Small, 0.13 <= eta < 0.26 – Medium, eta >= 0.26 - Large***

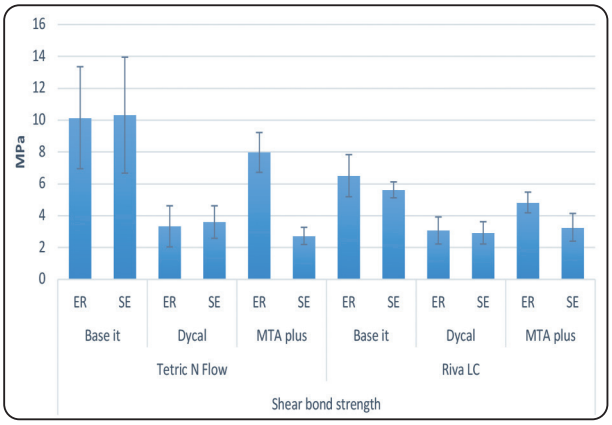

Fig. (1) Bar chart showing mean and standard deviation values (error bars) of shear bond strength for different variables

TABLE (3) Comparison of simple effects within **Tetric N Flow**

Conditioning protocol	**shear bond strength (MPa) (Mean±SD)**			**f-value**	**p-value**	**Partial eta squared (95% CI)**
	Base it	***Dycal***	***MTA plus***			
ER	10.15±3.20^{A}	3.33±1.29^{C}	7.97±1.25^{B}	**67.18**	**<0.001***	**0.444 (0.349:0.515)**
SE	10.31±3.64^{A}	3.60±1.02^{B}	2.73±0.54^{B}	**95.31**	**<0.001***	**0.532 (0.444:0.594)**
f-value	**0.07**	**0.20**	**75.99**			
p-value	**1**	**1**	**<0.001***			
Partial eta squared (95% CI)	**0.000 (0.000:0.017)**	**0.001 (0.000:0.024)**	**0.311 (0.218:0.395)**			

Means with different superscript letters within the same horizontal row are significantly different; *significant (p<0.05), eta < 0.02 - Very small, 0.02 <= eta < 0.13 – Small, 0.13 <= eta < 0.26 – Medium, eta >= 0.26 - Large

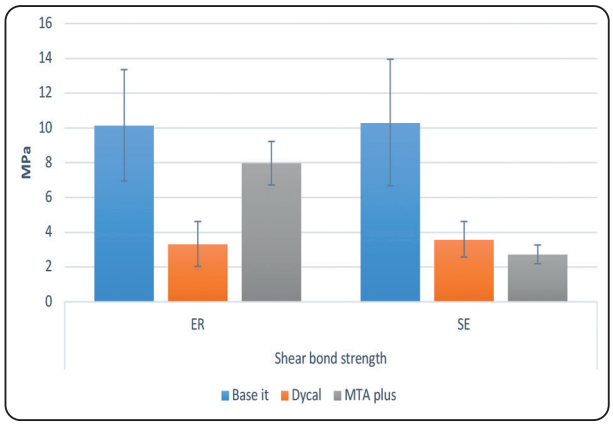

Fig. (2) Bar chart showing mean and standard deviation values (error bars) of shear bond strength within Tetric N flow (A)

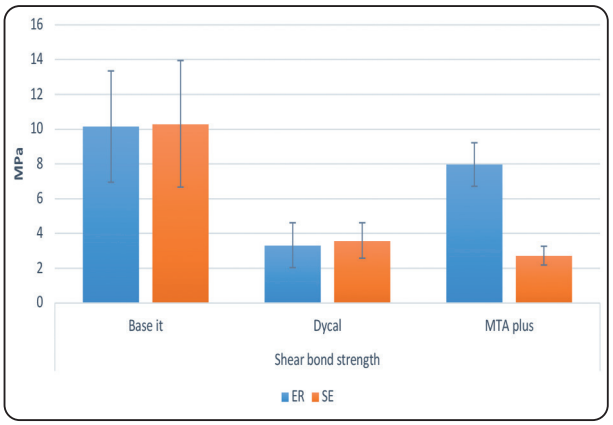

Fig. (3) Bar chart showing mean and standard deviation values (error bars) of shear bond strength within Tetric N flow (B)

TABLE (4) Comparison of simple effects within MTA plus

Conditioning protocol	shear bond strength (MPa) (Mean±SD)		f-value	p-value	Partial eta squared (95% CI)
	Tetric N Flow	*Riva LC*			
ER	7.97±1.25	4.83±0.65	**27.24**	**<0.001***	**0.140 (0.067:0.220)**
SE	2.73±0.54	3.27±0.87	**0.79**	**1**	**0.005 (0.000:0.036)**
f-value	**75.99**	**6.81**			
p-value	**<0.001***	**0.060ns**			
Partial eta squared (95% CI)	**0.311 (0.218:0.395)**	**0.039 (0.005:0.097)**			

Means with different superscript letters within the same horizontal row are significantly different; *significant (p<0.05), eta < 0.02 - Very small, 0.02 <= eta < 0.13 – Small, 0.13 <= eta < 0.26 – Medium, eta >= 0.26 - Large

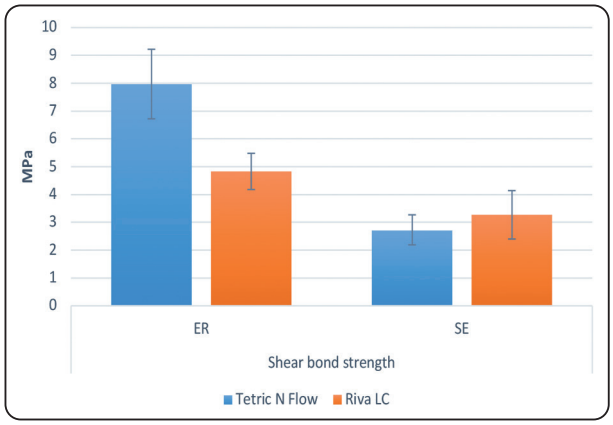

Fig. (4) Bar chart showing mean and standard deviation values (error bars) of shear bond strength within MTA plus (A)

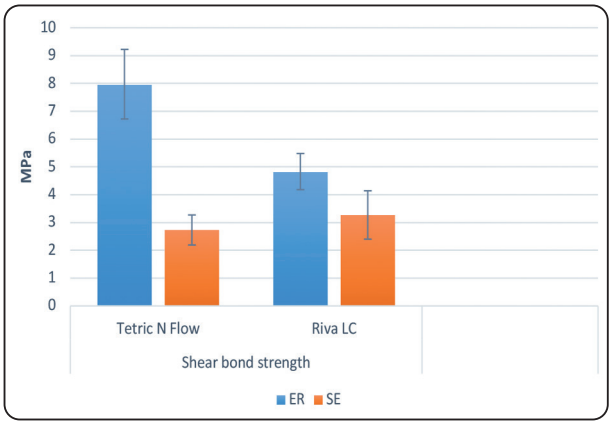

Fig. (5) Bar chart showing mean and standard deviation values (error bars) of shear bond strength within MTA plus (A)

TABLE (5) Comparison of simple effects within different conditioning protocols

Conditioning protocol	Restorative material	shear bond strength (MPa) (Mean±SD)			f-value	p-value	Partial eta squared (95% CI)
		Base it	*Dycal*	*MTA plus*			
ER	**Tetric N Flow**	10.15±3.20^{A}	3.33±1.29^{C}	7.97±1.25^{B}	**67.18**	**<0.001***	**0.444 (0.349:0.515)**
	Riva LC	6.51±1.32^{A}	3.07±0.85^{C}	4.83±0.65^{B}	**16.42**	**<0.001***	**0.164 (0.081:0.241)**
	f-value	**36.76**	**0.20**	**27.24**			
	p-value	**<0.001***	**1**	**<0.001***			
	Partial eta squared (95% CI)	**0.180 (0.099:0.263)**	**0.001 (0.000:0.024)**	**0.140 (0.067:0.220)**			
SE	**Tetric N Flow**	10.31±3.64^{A}	3.60±1.02^{B}	2.73±0.54^{B}	**95.31**	**<0.001***	**0.532 (0.444:0.594)**
	Riva LC	5.62±0.50^{A}	2.92±0.70^{B}	3.27±0.87^{B}	**11.95**	**<0.001***	**0.125 (0.052:0.198)**
	f-value	**61.04**	**1.30**	**0.79**			
	p-value	**<0.001***	**1**	**1**			
	Partial eta squared (95% CI)	**0.266 (0.175:0.351)**	**0.008 (0.000:0.044)**	**0.005 (0.000:0.036)**			

Means with different superscript letters within the same horizontal row are significantly different; *significant (p<0.05), eta < 0.02 - Very small, 0.02 <= eta < 0.13 – Small, 0.13 <= eta < 0.26 – Medium, eta >= 0.26 - Large

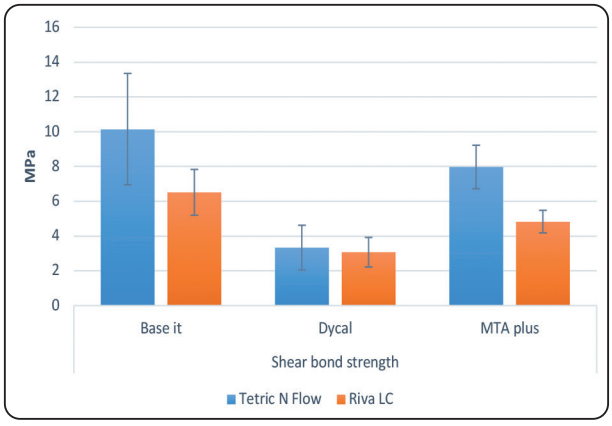

Fig. (6) Bar chart showing mean and standard deviation values (error bars) of shear bond strength within ER (A)

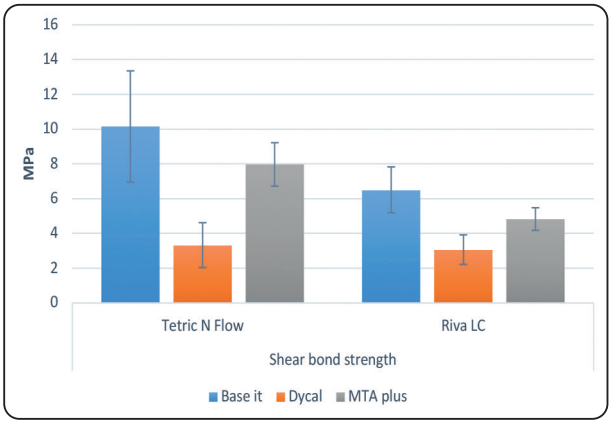

Fig. (7) Bar chart showing mean and standard deviation values (error bars) of shear bond strength within ER (B)

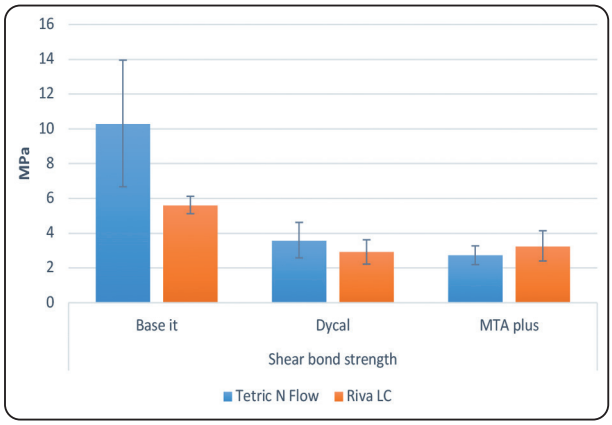

Fig. (8) Bar chart showing mean and standard deviation values (error bars) of shear bond strength within SE (A)

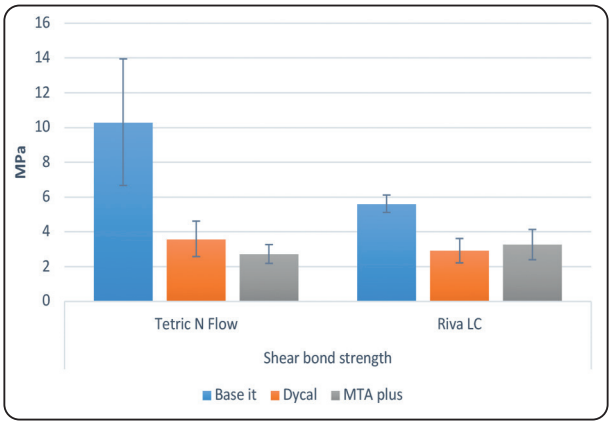

Fig. (9) Bar chart showing mean and standard deviation values (error bars) of shear bond strength within SE (B)

DISCUSSION

Vital pulp capping aims to maintain and sustain pulp vitality by eliminating infections and employing biocompatible chemicals to form a durable and potent barrier against microbial microleakage. [12] It is critical to maintain the pulpal health and seal it throughout this treatment. The most commonly used pulp capping agent is calcium hydroxide. However, another recent biocompatible material have gained popularity [13]. Recently, all efforts have been made to develop novel materials that need fewer application processes, hence lowering the danger of contamination and also the treatment time. [14]

Additionally, to achieve successful and durable restorations, these materials should be able to provide a good coronal seal as well as marginal integrity. Because of the decreased stresses put on the pulp capping biomaterial, resin composite is the ideal choice for ultimate restoration, especially in the esthetic zone. [15] On the other hand, RMGI can be an excellent restorative material in occasions of not enough enamel left surrounding the preparation. Bond between the pulp capping materials and composite resin or RMGI is critical in such restorations used as bases and liners in terms of sealing ability and finally in the treatment outcome. [16].

The common practice to evaluate the adhesive properties of restorative materials is via the assessment of bond strength. The shear bond strength method was selected because its application is generally straightforward and reproducible in most of the literature under laboratory circumstances [19,20]

The use of ER and SE strategies over different capping materials is recommended to gain a perfect peripheral seal with overlaying restorations for successful treatment outcome. [21,22].

Several studies reported that an ER system showed the utmost bond strength to resin composite because 35% phosphoric acid efficiently removes the smear layer, offering a clean surface for ideal micromechanical retention with composite, as well as its capability to produce deeper and more retentive micro porosities in tooth structures bases and sub- bases materials like pulp capping materials. The poor performance of SE adhesives is due to combining the acidic hydrophilic and hydrophobic monomers in single phase, which may impede adhesive polymerization process. Aside from poor adhesive strength and low degree of monomer polymerization which caused by the existence of a solvent-oxygen inhibitory impact during the polymerization of these SE adhesives [23,24 ,25].

Several investigations revealed that single-step self-etch adhesive solutions produced higher

bonding strength values to composite, which is ascribed to a high pH value as well as improving solvent wettability and diffusivity. The universal adhesive Tetric N –bond universal used in the current study was (mild- etching adhesive) has a pH of approximately 2.5 – 3.0. The TE adhesion strategy gives significantly higher SBS values than SE strategy. [26,27,28]

Recent research that assessed SBS of adhesives to MTA utilizing different bonding techniques found that an ER adhesive can produce superior MTA composite bond strength after 24 h compared to the SE adhesive. [21] This finding came in accordance with the result of the current study but came on the opposite of the study by Ansari et al, 2013 [15] that reported no significant difference between the MTA and the other tested capping materials. The explanation for that conclusion is etching of the MTA resulted in a selective loss of matrix around the crystalline structures [22] and subsequently an extensive porosity of the material [29]. This conclusion was suggestive for the increased surface area for micromechanical retention at the interface between the MTA plus material and the composite materials.

On the other hand, SE adhesives are gaining popularity due to their ease of application and lower method sensitivity. SE method employs acidic adhesive monomers that is responsible for demineralizing and permeating the dentin at the same time. The degree of the interaction of SE adhesive systems with dentin substrate was mostly determined by the acidity along with the aggressiveness of the primer utilized. [30,31,32] Therefore, two different adhesion strategies had been used in this study.

The light cured pulp capping material Base.it possess higher SBS value when compared to MTA Plus and Dycal, this can be attributed to the resin component, which forms a chemical bond with the resinous restorative materials, and a strong interface with the adhesive.

Base.it contains a hydroxy ions and phosphate ions, making it a good adhesion promoter and bond strengthener, which is the same resultant component after the setting process of the MTA plus. So, the unique apatite stimulating ability of both MTA plus and Base .it makes them ideal for vital pulp therapy. [33,34,35] Their ability to release calcium stimulates hydroxy apatite formation as well as their significant calcium release is well documented, which leads to a well protective seal [35,36,7]. MTA Plus use in the clinical situation gave an additional advantage by being more compatible than Base .it as its resin free [7]. On the other hand, the absence of resin in MTA Plus and Dycal shows that their bonding to composite resin and RMGIC is weak, as it's purely micromechanical. [37], which explained the results of this study within SE samples.

Superior result in the MTA plus group in comparison to Dycal group came from the material nature. The novel material MTA-Plus, which is declared to be a better substitute than the available MTA products that has been launched as they have a finer particle size [38]. Finer particle size is essential for the physical properties as it will enlarge the surface area susceptible for the hydration and enhance the early strength in addition to ease of handling, its mixture with anti-washout gel is expected to improve its anti-washout resistance. [39,40] That came in agreement with other studies concluded that being a tricalcium silicate materials which proved that in both clinical and radiographic investigations, all calcium silicate derivatives performed better than calcium hydroxide preparations for successful pulp capping therapy [41,42,43,44,45] .

The lower SBS of Dycal can be interpreted by its tendency to release fewer calcium ions than calcium silicate-based products. [46,47]. Dycal's low SBS value can be explained by the fact that adhesive systems with acidic pH cause softening and dissolution in this chemically setting material [44].

Moreover, it was found that Dycal worsen the bond strengths to the tested restorative material. And that is due to, it's break down when acid etchants are used. Thus, acid etching did not increase the value

of the bond strength. [48] Furthermore, absence of chemical bonding between Dycal and composite resin as well as RMGIC, together with the low cohesive strength of Dycal counts for the low SBS values.

When two distinct materials are employed in a restorative procedure, an adequate link between the two components is required [49]. Bond failure is generally considered to be accepted only when failure happens within each material comparatively than when occurred at the bonded interface (i.e., cohesive rather than adhesive [50]. Failure mode inspection and interpretation revealing greater percentage of cohesive failures in samples of the LC Base.it and MTA plus compared to Dycal, which primarily showed mixed failure modes, which is pointing to a stronger bond in the former groups. Previous research has found that a higher percentage of cohesive failure in examined specimens indicates a stronger bond strength. Accordingly, accepted bond strength is proved as the material itself failed before the adhesion failed between Base.it, MTA plus and restorative materials

Accordingly, the null hypothesis that was adopted is rejected as there was a difference statistically in the SBS of the whole tested pulp capping agents to the overlaying restorative materials with the different used adhesion strategies

Recommendations:

Additional investigations are required by examining the materials with dentin and with different storage periods.

CONCLUSION

- The adhesion strategy used influences the SBS of the tested capping materials.
- As light cured Calcium hydroxyapatite oligomer (Base.it®) had the highest SBS followed by self- curable mineral trioxides aggregates (MTA plus®). The capping material to be used should be bioceramic in nature to ensure successful vital pulp therapy.

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