Evaluation of Compressive Strength of Repaired Direct Composite Resin Restorations

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The aim of the study was to evaluate and to compare the compressive parameters of repaired composite restoration when using different types of composite resins and a universal bonding agent as an intermediate layer. Aged micro-filled hybrid and nano-filled hybrid composite resins were chosen to simulate old restoration. The same micro-filled hybrid composite resin was used as a repair material. A universal bonding agent applied in etch-and-rinse and self etch strategies was used as an intermediate layer in restoration repair. Non-aged composite resins were considered as control. Compressive strength and compressive modulus were determined by evaluating the samples in a universal testing machine. Lower values of the tested parameters were recorded after aging both types of composite resin when compared to control. Higher values of compressive strength were recorded when nano-filled hybrid composite resin was repaired when compared to micro-filled hybrid composite resin. The strategy of universal bonding agent application as an intermediate layer did not influenced the compressive properties of repaired restoration.

Keywords: restoration repair, composite resins, compressive strength, compressive modulus

Composite resins have become since early 60s the most commonly used materials for direct restoration. In oral cavity these materials are prone to chemical degradation due to the contact with saliva, acidic beverages and food, chemical agents used in dental treatment or to mechanical challenge due to dental contacts during functions. Many failures of composite restorations are directly related to their mechanical and physical properties as compressive and tensile strength [1]. Efforts were made during time in order to improve these characteristics by increasing the fillers content or decreasing the particles size of these dental materials. The longevity of composite resin restoration in oral cavity is directly related to the resistance to masticatory and parafunctional forces [2-6]. Therefore properties like the resistance to deformation and fracture, to tensile and compressive failure are also good indicators for clinical success.

Repair of a fractured restoration is considered to be a better method for treatment then the replacement [7]. In this procedure a new layer of material is added in contact with an old one from which a part had been removed during the functioning of the restoration or deliberately by the practitioner. The efficacy of composite repair is related to the long-term retention between the two different surfaces in direct contact. In previous studies different methods for surface treatment and many intermediation agents were evaluated in order to provide a better adhesion of the materials used in composite repair [8-10]. It was stated that a bonding agent increases the adhesiveness of repaired surfaces due to surface wetting and chemical bond with the new composite [11, 12].

There is a lack of evidence regarding the influence of the type of composite resins used in restoration repair on mechanical properties of the final restoration. The aim of the study was to evaluate and to compare the compressive parameters of repaired composite restoration when using different types of composite resins and a universal bonding agent as an intermediate layer.

Experimental part

Resin specimens preparation

A micro-filled hybrid (Zmack, Zhermack Sp.A, Germany) (MH) and a nano-filled hybrid (Premise, Kerr Co) (NH) composite resin were used for this study. The chemical composition of the materials is presented in table 1. Twenty specimens of each material were obtained by placing the composite resin into moulds having 5 mm diameter and 6 mm height. Two layers of 1.5 mm were placed, each layer being polymerized for 40 s with a LED curing unit (LED B, Guilin Woodpecker Medical Instrument Co., Ltd, China) having the light intensity of 850-1000mW\cm^2 and the wavelength of 420-480 nm. A translucent Mylar strip and a 2mm thick glass slab were placed at the bottom of the mould in order to flatten the surface and to prevent the formation of the oxygen inhibited layer. Ten specimens of each material were used to obtain control samples and ten specimens were aged by storing in artificial saliva (AFNOR NF S90-701) for four months.

Composite resin repair and samples preparation

The micro-filled hybrid composite resin (Z-mack, Zermack Sp.A.) was used as a repair material for all the groups. The material was placed in direct contact with the non-aged and aged NH and MH composite resins by an intermediate layer of a universal bonding agent (G Premio Bond, GC Corporation) (UBA). The bonding system was used in two different strategies: etch-and-rinse (strategy 1), and self-etch (strategy 2). The layout of the groups are presented in table 2.

In strategy 1, 35% phosphoric acid etchant gel (3M-ESPE, St. Paul, MN, USA) was applied for 30 s on surface of the resin specimens, then removed using the water from the dental unit spray and gently dry using the air spray. UBA was applied according to the producer instructions, by scrubbing the resin surface for 20 s , gently air drying for 5 s and then lightcuring for 20 s. In strategy 2 the application of UBA was similar as in strategy 1, excepting the etching step.

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Table 1

CHEMICAL COMPOSITION AND CHARACTERISTICS OF COMPOSITE RESINS

Product	Producer	Filler type	Filler content in weight	Filler content in volume	Matrix type
Z-mack	Zhermack Sp.A	Barium glass Silica	77%	57%	Bis-GMA, Bis-EMA TEGDMA
Premise	Kerr Co	Barium alumino borosilicate glass, silica, PPF, barium glass	84%	69%	Bis-GMA Bis-EMA TEGDMA

Table 2

LAYOUT OF CONTROL AND STUDY GROUPS

Materials/group			**Groups**							
			1	2	3	4	5	6	7	8
Initial restorative material	Micro-hybrid MH	non-aged (control)	X	X						
		aged (study)			X	X				
	Nano-hybrid NH	non-aged (control)					X	X		
		aged (study)							X	X
Adhesive	Strategy 1	Preliminary etching		X		X		X		X
	Strategy 2	No etching	X		X		X		X	
Material used for the reparation			X	X	X	X	X	X	X	X

The repair composite was applied in contact with non-aged or aged specimens in two increments of 1.5 mm each.

Different shades of composite resins were used to simulate the restoration repairment in order to facilitate the identification of the materials.

Samples from groups 1, 2, 5, 6 were removed from the moulds and used as controls. The samples included in the study groups (3, 4, 7, 8) were stored in artificial saliva for another 2 months and then they were removed from the moulds.

Evaluation of compressive parameters

Each sample was tested to determine the compressive behavior using a universal testing machine (MTS 810 Material Test Systems, MTS System Corporation, USA) with a load cell of 100 kN and a crosshead speed of 0.5 mm/min (fig.1). Two compressive parameters were recorded for the samples: peak stress (compressive strength) and compressive modulus, both expressed in MPa [13-15].

Results and discussions

Examples of compressive strength curves for some samples in groups 3, 4, 7 and 8 are presented in figures 1-5. Similar aspect of the curves was obtained when compared the samples in groups 3, 4, 7 and 8 (fig. 6). The mean values of compressive strength and modulus are presented in table 3.

Lower values of compressive strength were recorded in groups 3 and 4 when compared to groups 1 and 2, respectively. The same tendency was recorded even in groups 7 and 8 when compared to groups 5 and 6. The lowest compressive strength values in study groups were recorded in group 3 and the highest in group 8. In control groups the lowest value of compressive strength was recorded in group 1 and the highest in group 5. In groups 5-8 increased values of compressive strength were registered when compared to corresponding groups 1-4.

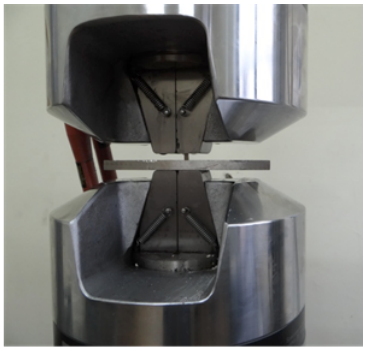

Fig.1. Aspect of a sample mounted onto the universal testing machine

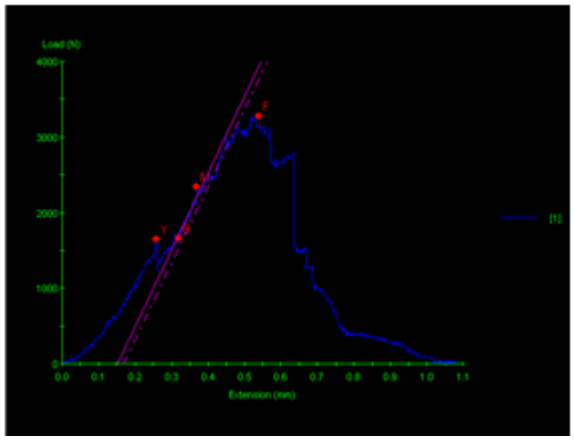

Fig.2. Compressive strength curve for a sample in group 3

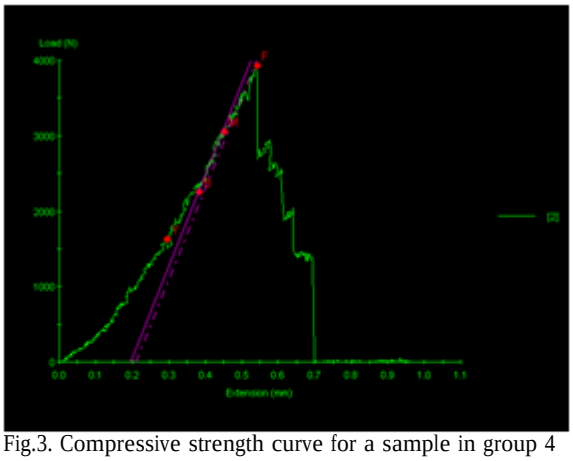

Fig.3. Compressive strength curve for a sample in group 4

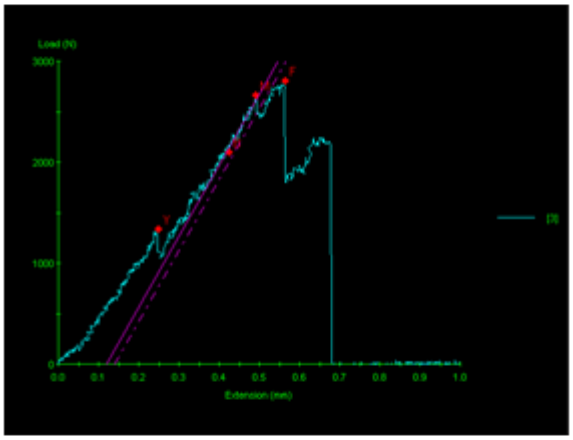

Fig.4. Compressive strength curve for a sample in group 7

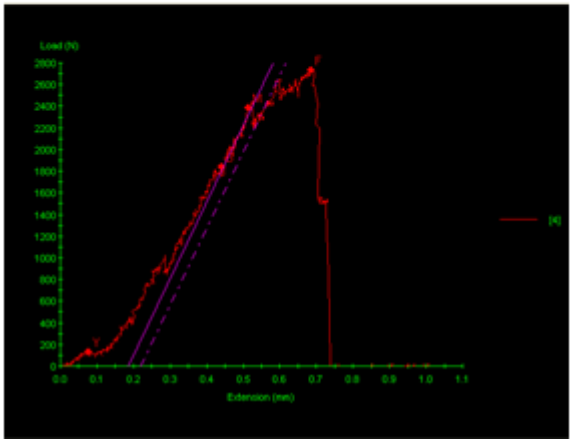

Fig.5. Compressive strength curve for a sample in group 8

In groups 3 and 4 the compressive modulus values were higher when compared to groups 1 and 2, respectively. Also in groups 7 and 8 the values were higher when compared to groups 5 and 6, respectively. In study groups the lowest compressive modulus value was recorded in group 7 and the highest in group 4. In control groups the lowest value of compressive modulus was recorded in group 5 and the highest in group 2. In groups 5-8 decreased values of compressive modulus were registered when compared to corresponding groups 1-4.

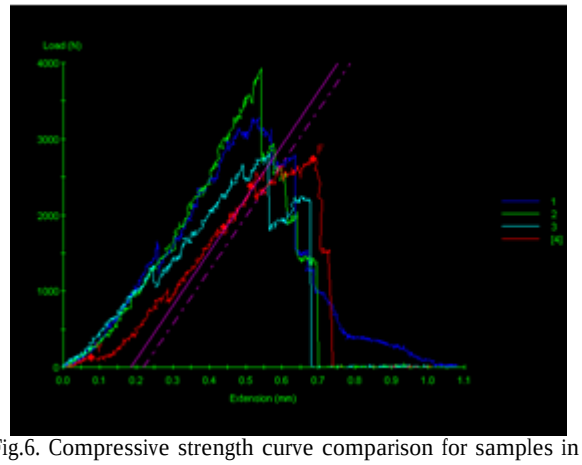

Fig.6. Compressive strength curve comparison for samples in groups 3, 4, 7 and 8

The values were statistical analyzed using Mann-Whitney U statistical test. No statistically significant differences were obtained when compared the mean values of compressive strength in all study groups when compared to control and between study groups (2-tailed > 0.05) (table 4). Also, no statistically significant differences were recorded when compared the mean values of compressive modulus in all study groups when compared to control and between study groups (2-tailed > 0.05) (table 5).

After aging, decreased values of compressive strength were recorded for both micro-filled hybrid and nano-filled hybrid repaired composite resins. Previous studies also demonstrated that artificial aging decreases the compressive strength [13-16]. In our study increased values of compressive strength were registered for repaired nano-filled hybrid composite resin when compared to micro-filled hybrid composite resin. Mechanical properties are directly related to the type of filler, the filler content and the coupling agent [17]. In the present study the composite resin having higher amounts of the fillers showed better mechanical results. Other studies also demonstrated this correlation [18]. A possible explanation for this condition might be due to the fact that smaller particles size are related to a higher filler content by volume and a better distribution of the filler. In this way the distance between particles is smaller and the contact area increased [19].

The teeth are subjected in the oral cavity to mechanical cycles and the composite resins used for direct restoration might be prone to fatigue, fracture or failure [1]. Except the filler size, the matrix type, curing time, the type and degree of polymerization and polymerization shrinkage are

Table 3

MEAN VALUES OF COMPRESSIVE PARAMETERS

Parameters of compressive evaluation	Groups							
	1	2	3	4	5	6	7	8
Peak stress (MPa)	197.66	198.42	193.06	195.43	203.22	201.87	193.97	196.14
Modulus (MPa)	4436.21	4682.33	4170.22	4202.25	4272.06	4367.54	3787.48	3815.94

	Z	Asymp. Sig. (2-tailed)
Group 1- Group 3	-2.611	0.09
Group 2-Group 4	-2.611	0.09
Group 3-Group 4	-2.611	0.09
Group 5-Group 7	-2.611	0.09
Group 6-Group 8	-2.619	0.09
Group 7-Group 8	-2.611	0.09

Table 4
MANN-WHITNEY U STATISTICAL TEST RESULTS FOR COMPRESSIVE STRENGTH VALUES COMPARISON

	Z	Asymp. Sig. (2-tailed)
Group 1- Group 3	-2.611	0.09
Group 2-Group 4	-2.611	0.09
Group 3-Group 4	-2.611	0.09
Group 5-Group 7	-2.619	0.09
Group 6-Group 8	-2.611	0.09
Group 7-Group 8	-2.611	0.09

Table 5
MANN-WHITNEY U STATISTICAL TEST RESULTS FOR COMPRESSIVE MODULUS VALUES COMPARISON

important factors that might influence mechanical strength [20]. Also, the composition of saliva, the presence of various chemical substances [21] or the storage medium of *in vitro* studies [22, 23] have been reported to have a direct impact on mechanical properties. For a material used for direct restoration, especially on posterior region, compressive strength represents the most important mechanical property [24-27]. Ideally, the restorative material might have the same mechanical characteristics as dental hard tissues. Different properties could affect the resistance of both tooth and restoration. A previous study estimated the compressive strengths of enamel and dentine of being 384 MPa and 297 MPa, respectively [28]. Unfortunately, the compressive strength values of repaired composite resins in the present study were much lower than for enamel and dentine. Also the compressive moduli of the materials tested in the present study were lower than for dentine (11.0–18.5 GPa) [29]. Restorative materials having low compressive modulus could respond to oral stress by absorbing it if the stress is lower than the strength or by fracturing if the stress is higher than the strength.

However the differences between the groups were not statistically significant. These results suggest that repairment technique provide compression strengths comparable to new restorations regardless the type of old composite materials and adhesive strategy used for bonding. Future studies should evaluate other mechanical characteristics and also take into consideration the influence of reparation on the behavior of the supportive dental tissues.

Conclusions

Irrespective of the type of repaired composite resin, aged materials presented a lower compressive strength and modulus than non-aged materials. The repaired nano-filled hybrid composite resin had a higher compressive strength when compared to repaired micro-filled hybrid composite resin. The differences were not statistically significant suggesting that the repairment of old restoration might constitute viable alternatives in terms of resistance to compressive stress in the oral environment. The application strategy of the universal adhesive as an intermediate layer did not influenced the compressive properties of repaired restoration.

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