Aspects in Effectiveness of Glass- and Polyethylene-Fibre Reinforced Composite Resin in Periodontal Splinting

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The aim of study was to evaluate some aspects in the clinical effectiveness of fibre-reinforced composite resin periodontal splints on mobile teeth. Fibres-reinforced composite resin retainers are recommended likewise in the treatment of teeth mobility. The study group was formed by a total of 62 patients, which presented first and second mobility degrees of anterior teeth (436 included teeth into research). 42 patients belonging to the experimental group with periodontal splinting, benefited by Interlig-Angelus glass-fibers and Ribbond-Seattle polyethylene-fibres reinforced composite resin splints (295 splinted teeth and 50 splints). The used composite resin was represented by Vertise™ Flow-Kerr. 20 patients (141 teeth) represented the control group, without splinting. All included patients followed periodic monitoring visits (after a week and at one month, for a period of 6 months), in order to evaluate the detaching degree/adhesive failure of reinforced composite resin splints and the reducing of dental mobility degree. The results of study revealed that between the two types of immobilization splints there was no significant difference in the degree of separation/adhesion failure, in the acceptability or in the patient's comfort. Both types of fiber-reinforced composite resin periodontal splints had beneficial effects in decreasing the degree of dental mobility and it was remarked their aesthetic acceptability, respectively the patient's comfort.

Keywords: composite resin, glass- and polyethylene-fibers, periodontal splinting

Periodontitis is characterized by gingival inflammation and loss of connective tissue attachment and alveolar bone. Classical symptom of periodontitis is increased tooth mobility [1]. Splinting in periodontology usually refers to joining together tooth/teeth having mobility [2]. The reasons to stabilize periodontally compromised teeth have beneficial action in maintaining/healing the mobility degree of affected teeth, including the decreased patient discomfort, increased occlusal and masticatory function, and improved prognosis of mobile teeth [3]. The direction of the applied forces to the splinted teeth is beneficially modified by converting the lateral loads into vertical ones that are less harmful for the tooth supporting splints [4,5]. One of the main factors in healing is represented by splint flexibility, which is related to the degree of allowed movement [6]. The best semi-physiological mobility can be obtained by means of flexible splints [7].

Manny different materials are used for periodontal splinting, which include composite-wire and composite-fibre reinforced splints. In the medical field, the composite materials are used because they are chemically stable and do not introduce negative effects, the human body easily tolerating them [8]. The most common materials currently used in order to achieve fiber-reinforced composite resin splints (=FRCRS =ribbon-splints) are glass- and polyethylene-fibers. Fibers were developed so that they can reinforce the dental composite resins, in order to form thin, but strong splints. Glass-fibers are treated with a silane chemical coupling agent to allow dental resins to chemically adhere to the glass fiber strands. The polyethylene fibers are chemically treated thorough plasma treatment, which allows the resin to chemically bond to the polyethylene fibers. Without this treatment, there would be no surface wetting of resin and bonding between the 2 substrates [6].

The evaluated FRCRS in this study for immobilising anterior mobile teeth was reinforced with glass-fibers (Interlig, Angelus) and polyethylene-fibers (Ribbon-THM, Ribbon).

Interlig-Angelus glass fibers (fig. 1) are braided malleable glass fibers, preimpregnated with light-cured composite resin, easy handling, easy to cut (special scissors are not required) and adapt, packed in sachets for protects fibers from light and heat (3 Strips 85.0 * 2.0 * 0.2 mm) [9].

Ribbond-THM reinforcement ribbon (Ribbond Inc., Seattle, WA) for periodontal splint is bondable reinforced polyethylene fibers, consisting of ultrahigh modulus, ultrahigh strength and molecular weight fibres. Is designed for use with applications in which thinness and higher modulus are the primary concerns. These thinner fibers

Fig. 1. Presentation mode of Interlig glass-fiber and Ribbond-THM polyethylene-fibres

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Fig. 2. Presentation mode of Vertise™ Flow (Kerr) composite

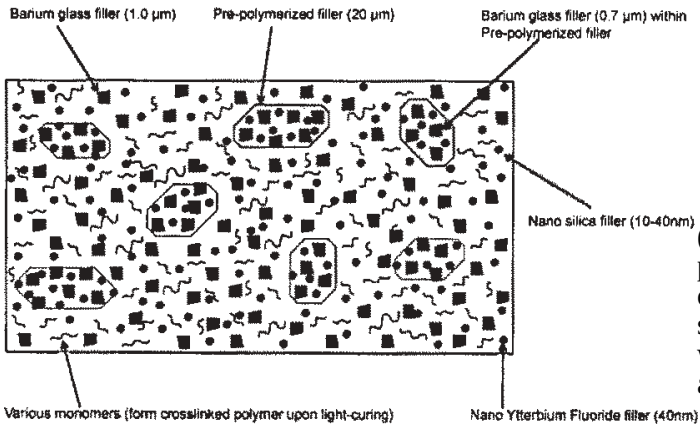

Fig. 3. The component nanoparticles of Vertise™ Flow (Kerr) composite resin

with a higher thread count far exceed the breaking point of fiber-glass and are so tough that specially made scissors are required to cut them. These fibers have only 0.18 mm thick, and are treated with cold gas plasma to enhance its adhesion to synthetic restorative materials, including chemically cured or light-cured composite resins. Its composition utilizes pre-impregnated, silanized, plasma treated, ultra high molecular weight (UHMW) polyethylene fibres (fig. 1).

Vertise™ Flow - Kerr (fig. 2) is a new category of self-adhering flowable composite which not require separate bonding step, with high bond strengths to dentin and enamel and high adhesion.

This composite consists of 4 filler types (fig. 3): prepolymerized filler, 1-micron barium glass filler, nano-sized colloidal silica, and nano-sized Ytterbium fluoride. The average particle size of Vertise™ Flow is 1 micron. The pre-polymerized filler (PPF) help minimize shrinkage, enhances the handling characteristics of the material, making it smooth and easy to manipulate. Nanoparticles enhance the polishability of the material and achieve special rheological property, or thyxotropic, nonslumping behaviour. Nano-ytterbium fluoride particles give Vertise™ Flow radiopacity index (of 320%) for easy detection with X-rays.

Vertise™ Flow composite has an acidic phosphate group (for etching the tooth structure and also for chemically bonding to the calcium ions within the tooth structure), two methacrylate functional groups (for copolymerization with other methacrylate monomers to provide increased cross linking density and enhanced mechanical strength for the polymerized adhesive) (fig. 4)[10].

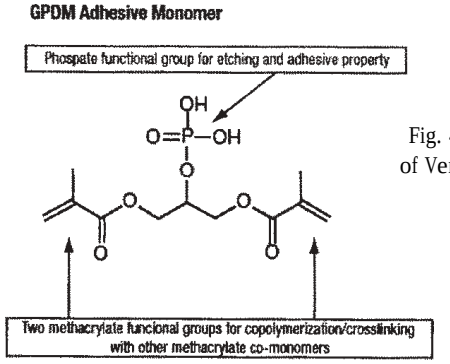

Fig. 4. Adhesive action of Vertise™ Flow System

Experimental part

Our clinical study was designed as case series and was conducted in Dental Medicine Faculties of Tirgu-Mures University of Medicine and Pharmacy, respectively of Titu Maiorescu University of Bucharest, between April 2013 and March 2015.

The tested null hypothesis was that there would be no difference between the two types of used splint materials, in terms of their clinical effectiveness.

The study group were formed by a total of 62 patients (33 females, 29 males, mean age: 45 years old), which presented first and second degrees mobility of maxillary or/and mandibular anterior teeth, had undergone non-surgical periodontal treatment and occlusal adjustment where was necessary and had the recommendation for applying periodontal splints.

42 patients belonging to the experimental group benefited by FRCRS achieved by Interlig-Angelus glass-fibers (21 patients, 12 females, 9 males, mean age: 45 years old, with 143 splinted teeth, 24 FRCRS) and Ribbond-Seattle polyethylene-fibers (21 patients, 12 females, 9 males, mean age: 45 years old, with 152 splinted teeth, 26 FRCRS). The flowable composite resin represented by Vertise™ Flow-Kerr was tested in combination with the two used fibers for FRCRS.

20 patients (9 females, 11 males, mean age: 44 years old with 141 anterior teeth with mobility), represented the control group, without FRCRS.

The distribution of patients in groups, after gender, number of included teeth and the used fibers for reinforcement is presented in figure 5.

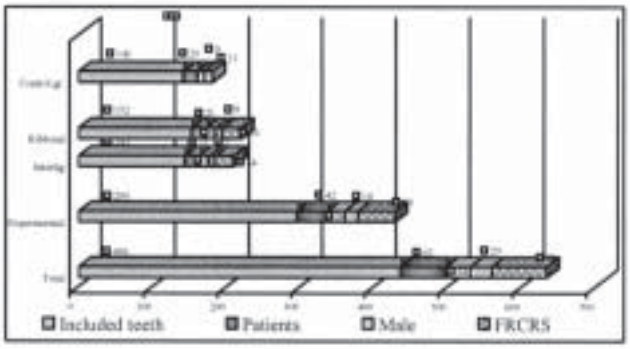

Fig. 5. The distribution of patients in groups, after gender, included teeth and used fibers

The exclusion criteria of patients for collection of data were represented by the patients who had used antimicrobial mouthwashes, antibiotics within the previous 3 months of the study and have systemic disease.

The inclusion criteria of patients in the trial were represented by the patients who presented good tooth brushing and mouth-rinsing after their special training.

All patients received oral prophylaxis at the start of the study. After the removal of dental calculus deposits, the teeth were cleaned by using fine pumice, prophylaxis brush on a slow-speed hand-piece, water slurry and rubber cups. In both groups, patients received oral hygiene instructions in the use of interdental brush, additionally to Bass method of tooth brushing.

The used bonding technique to connect the mobile teeth each other by reinforcing with fibers was the bonding method with Vertise™ Flow composite resin. The enamel of lingual surface of selected teeth were washed and gently

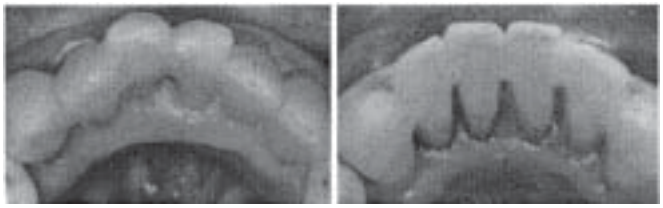

Fig. 6. The aspect of two FRCS: left: with Interlig-Angelus; right: with Ribbond-Ribbond Inc.

air-dried. Fibers were measured and cut to the desired dimension. A thin layer of Vertise™ Flow resin was applied on the enamel surfaces by using a microbrush and left uncured. The cut ribbons were carefully adapted on the lingual surfaces of anterior teeth into the uncured composite, pushed into the embrasures and a new thin layer of flowable resin were applied. The excess of composite resin was removed before light curing. Each segment of splints was light-cured for 20 seconds. A new layer of flowable resin was applied on splints and each segment was light-cured for 30 s, to be certain that the light penetrated in the ribbon and the composite resin is completely cured. The occlusion was checked and adjusted if it was necessary and the surface of composite resin was finished with burs for composites. The polishing was realised with hand-piece at 3000 rpm, with polishing paste, in order to not expose the fibers of ribbons.

Patients were informed about possible complications and instructed to call upon experience of a failure. After one week, all patients were recalled to monitoring their oral hygiene, occlusion and the presence of possible composite resin remnants.

The aspect of used periodontal splints, reinforced with Interlig-Angelus glass-fibers and Ribbond-Ribbond polyethylene-fibers, are presented figure 6.

In order to evaluate the detaching degree of reinforced composite resin splints and the decreasing degree of dental mobility, all included patients followed periodic monitoring visits after a week and at one month, for a period of 6 months, therefore a total of seven monitoring visits.

Detaching/adhesive failures of FRCRS were evaluated and classified as follows: A=adhesive failure (failure between enamel and composite resin), C=cohesive failure in resin (failure in composite resin thickness), F= fibers failure (failure in fibers thickness) and M=mixed failure (a combination of the above).

The assessments of teeth mobility degree in both groups of patients (experimental-with FRCRS and control) were realised after 6 months and were conducted in accordance to the following: A=good amelioration of mobility, B=few amelioration of mobility, C=none amelioration.

Each patient of experimental group (with FRCRS) was asked about the esthetic result of retainer (visibility while talking and smiling), by means of VAS (Visual Analogue Scale) in which the 0 point means poor esthetic result effect and 10 means excellent esthetic effect.

Results and discussions

The evaluation of the detaching degree/adhesive failure of reinforced with fibers composite resin splints is presented in table 1.

Failures in FRCRS with Interlig-Angelus (Kerr) glass-fibers (24 splints on 143 teeth) were detected after 2 months (at third monitoring visit). In total, appeared 14 failures, 5 adhesive, 3 cohesive, 3 fiber and 4 mixed failures in 25 teeth from a total of 143 splinted teeth. Only one FRCRS reinforced with Interlig glass-fibers presented an oblique fissure during the study, but the fissure of composite resin was apparent, and the composite resin or the splint did not separate from the lingual surface of the teeth.

Failures in FRCRS with Ribbond-THM (Ribbond Inc.) polyethylene-fibers (26 splints on 152 teeth) were identified after 2 months (at third monitoring visit). In total, appeared 13 failures, 5 adhesive, 4 cohesive, 2 fiber and 2 mixed failures, in 23 teeth from a total of 152 splinted teeth.

The evaluation of the mobility degree in FRCRS after 6 months of immobilisation with FRCRS is presented in table 2.

The degree of mobility is decreased in both the groups (experimental and control), but this decrease was more pronounced in the experimental group (95.93%), compared to control group (26.24%). In experimental group, more reduction of tooth mobility appeared in Ribbond group (96.04%), compared to Interlig group (95.80%) (table 3).

The null hypothesis of the study was partially rejected, because no significant difference was detected between

Monitoring visits	Failures in FRCRS (24) with Interlig fibers (143 teeth)					Failures in FRCRS (26) with Ribbond fibers (152 teeth)				
	A	C	F	M	Total failures	A	C	F	M	Total failures
After 1 week	-	-	-	-	-	-	-	-	-	-
After 1 months	-	-	-	-	-	-	-	-	-	-
After 2 months	1 (3 teeth)	1 (1 tooth)	-	-	**2 (4 teeth)**	1 (2 teeth)	-	-	-	**1 (2 teeth)**
After 3 months	1 (2 teeth)	-	-	1 (1 tooth)	**2 (3 teeth)**	1 (3 teeth)	1 (1 tooth)	-	-	**2 (4 teeth)**
After 4 months	1 (4 teeth)	1 (1 tooth)	1 (1 tooth	1 (1 tooth)	**4 (7 teeth)**	2 (3 teeth)	1 (1 tooth)	-	-	**3 (4 teeth)**
After 5 months	2 (4 teeth)	-	1 (1 tooth)	1 (2 teeth)	**4 (7 teeth)**	-	1 (1 tooth)	1 (1 tooth)	1 (2 teeth)	**3 (4 teeth)**
After 6 months	-	1 (1 tooth)	-	1 (3 teeth)	**2 (4 teeth)**	1 (4 teeth)	1 (1 tooth)	1 (1 tooth)	1 (3 teeth)	**4 (9 teeth)**

Table 1
THE EVALUATION OF DETACHING/ADHESIVE FAILURES IN FRCS

Monitoring Visit	Teeth belonging to the experimental groups (295 teeth)												Teeth belonging to the control group (141 teeth)					
	Splinted teeth with Interlig fibers (143 teeth)						Splinted teeth with Ribbond fibers (152 teeth)											
At presenting	Teeth with I-st degree of mobility 29			Teeth with II-nd degree of mobility 114			Teeth with I-st degree of mobility 33			Teeth with II-nd degree of mobility 119			Teeth with I-st degree of mobility 26			Teeth with II-nd degree of mobility 115		
	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
After 6 months	28	1	-	96	12	6	30	3	-	101	12	6	3	8	15	11	15	89

* A–good amelioration of symptoms, B–few amelioration of symptoms, C–none amelioration

Table 2
THE EVALUATION OF MOBILITY DEGREE IN EXPERIMENTAL AND CONTROL GROUP AFTER 6 MONTH

Groups		A	B	Total	C
Experimental	Interlig (143 teeth	86.71%	9.09%	**95.80%**	**4.19%**
	Ribbond (152 teeth)	86.18%	9.86%	**96.04%**	**3.94%**
	In total (295 teeth)	86.44%	9.49%	**95.93%**	**4,06%**
Control (141teeth)		9.92%	16.31%	**26.24%**	**73.75%**

* A–good amelioration of symptoms, B–few amelioration of symptoms, C–none amelioration

Table 3
THE PERCENTAGE OF THE OBTAINED RESULTS IN THE MOBILITY DEGREE OF STUDIED TEETH

the percentages in the mobility degree of studied teeth immobilised with the two types of FRCRS.

After studying the recorded statements from patients, according to scale VAS (Visual Analogue Scale, in which the 0 point means poor esthetic result effect and 10 means excellent esthetic effect), we found that the esthetic result in used FRCRS was situated between 8-10 points.

Additionally, all patients of the experimental group reported the improvement of masticatory comfort after placement of the reinforced splints.

No adverse reaction was observed.

It was observed a higher degree of dental plaque index in the unsplinted teeth as compared to splinted teeth with FRCRS, but statistically, no significant difference appears between the studied groups.

The advantages of manufacture periodontal splints directly in oral cavity are multiple: the procedure can be effectuated in one appointment; with the exception of the fibre-mesh material, not requires unusual materials; the bonded splints are less invasive on the abutment teeth; interdentally spaces may be shaped, to facilitate the access for oral hygiene; repairs can be performed directly in oral cavity, without any complicated techniques or materials. Another advantage are represented by the facts that all adjustments regarding the design, the esthetic details and the occlusal and soft-tissue relationships, can be performed immediately, with a minimum of time, during monitoring appointments.

Hallmon and all [11] claims that reduced periodontal attachments determine the apparition of tooth mobility and migration, causing misaligned occlusal forces. Checherita and all [12] states that a proper examination and differential diagnosis is necessary to lead to a decision regarding the appropriate role of splint therapy and that it should be take in consideration both the physical and chemical properties of materials used to manufacture splints and the behaviour of dental materials in the oral cavity. After Littlewood and al [13], the factors which influence the success and longevity of FRCRS are the material type used for splinting, the composite resin type used for bonding, the number of dental units included for bonding and the location of splint (maxillary or mandibular dental arch). Renkema and al [14] states that lingual retainers are generally used for long-term retention purposes and after Ruse and al [15], lingual splints are subjected in clinical conditions to cyclic stresses as a result of mastication, occlusion and intra-oral habits.

Cacciafesta and al [16] claims that, even with higher flexibility of polyethylene-fibers versus glass-fibers reinforced composite resin retainers, some limitations in the clinical use of polyethylene FRCRS still persist, because the polyethylene-fibers were found to be significantly rougher than glass-fibers and resin based restorative materials, and this roughness can result in a higher retention of bacteria than in the other materials tested. The researches of Vallittu [17], sustain that reinforcement of polymers with a ribbon layer slightly increases the transverse strength, but the adherence of the polyethylene-fibers to the base polymer have been shown to be poor.

Lie Sam Foek and al [18] states that fiber-glass ribbons were introduced into fiber-reinforced composite resin splints for replacing wire retainers, and so, providing chemical adhesion of the splinting material to the bonding agent. After Ganesh and Tandon [19], the factors which influence the physical properties of fibre reinforced structures are the fibre loading within the restoration, respectively the efficacy of the bond at the fibre resin interface, fibre orientation and fibre position. The researches of Tanner and al [20] concluded that in the oral environment, polyethylene-fibers reinforced composite resin retainers promotes plaque accumulation and adhesion of microorganisms more than glass-fiber reinforced composite resin retainers, restorative composite and dental ceramic. According to studies conducted by Singla and al [21], fiber-reinforced composite splints combine the chemical, adhesive, and aesthetic characteristics of composite resin with the strength of a thin, high-elastic-modulus reinforcing ribbon. The researches of Chandra and al [22] referring to the bonded polyethylene fiber reinforcement ribbon and stainless steel wire plus composite resin splint have showed good compatibility with the gingival tissues and oral mucosa, without side effects. After Brauchli and all [23], the most important advantage of fiber-reinforced composite resin splints is their high transparency, which makes these retainers almost invisible.

In light of minimal-invasive dentistry, this new approach promotes a more conservative splinting, based on the effectiveness of current enamel-dentine adhesives and composites [24]. After Grandini and al [25], the adhesive splint material and the tooth are exposed to repeated subcritical loads during the masticatory process, and by the induced fatigue, can appear the partial or total failure of one or more components of this system. Dahl and al [26], presented favourable results concerning the survival of lingual splints, and the percent of breakage of the retainer material and the debonding of composite resin that bonded the ribbon fibers onto the tooth surface has been reduced. Noditi and al [27] underline that the advantages of the direct technique for creating the provisional restorations consist of a practical and quick fabrication with low cost. After the researches of Bolcu and all [28], under the action of external forces, the punctual fracture of a reinforcement thread makes the loading to be taken over by the others fibers in respective area.

In the specialty literature [29,30], there is great controversy about *in vivo* failure-survival rates of lingual retainers, *in vitro* testing of different retainer materials and the interpretations of results. The factors which can induce the fatigue effect on composite resin dental materials are these associated with the cyclic load (quantity, magnitude, direction of load application) and these related with the tested material (type of reinforcement, filler-matrix ratio, interfacial strength).

Based on the results of their study, Julosky and al [31] concluded that the fiber reinforcement of flowable composite does not affect its shear bond strength to ungrounded enamel and that the flexural strength of fiber reinforced composite resin retainers are significantly influenced by fiber composition and pattern. Meiers et al [32], tested the debonding force of fiber-reinforced composite retainers and concluded that debonding force was not dependant on the type of adhesive resin used, whereas Scribante et al [33], suggested the use of a specific lingual retainer adhesive instead of a flowable composite to achieve better results.

Vertise™ Flow composite [34] bonds in two ways: primarily through the chemical bond between the phosphate functional groups of a GPDM monomer and calcium ions of the tooth, and, secondarily, through a micromechanical bond as a result of an inter-penetrating network formed between the polymerized monomers of Vertise™ Flow and collagen fibers (as well as the smear layer) of dentin. The tight interface obtained to enamel and dentin demonstrates the self-adhering capacity of the self-adhering flowable composite. SEMs show tight

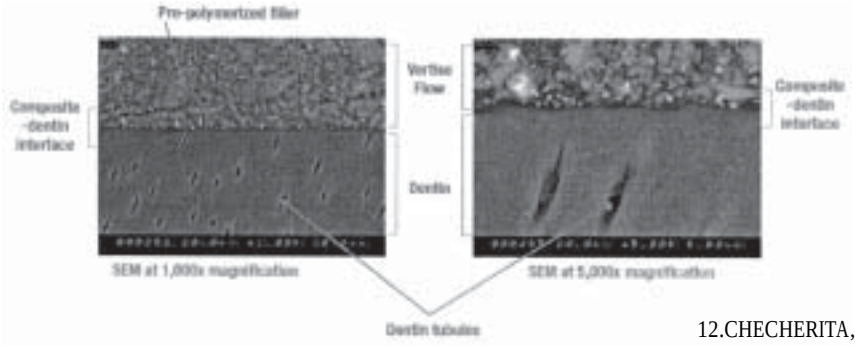

Fig. 7. SEMs of interfacial adaptation to dentin of Vertise™ Flow

interfacial adaptation of Vertise™ Flow to dentin, indicating good wetting and bonding capacity (fig. 7).

In conformity with the study of Ahrari and al [35], light cure adhesive and flowable composite showed excellent biocompatibility of bonding adhesive resins. Martha and al [36], states that etching with a self-etching primer cause just a moderate demineralization of the enamel surface.

Tayab and al [37] claims that in dentistry, both glass- and polyethylene-fiber has tremendous potential as reinforcement, but understanding the unique characteristics of each fiber type will enable the clinician in making appropriate choices during framework construction.

Conclusions

The reinforcement fibers used in research, have presented very good clinical effectiveness.

Both types of FRCRS used in the experimental group, have proven their beneficial qualities in decreasing the dental mobility degree of anterior teeth, compared with teeth of control group.

Concerning the detaching/adhesive failures, no significant difference was detected between the percentages of failures in the two types of FRCRS.

Both FRCRS type have demonstrated their excellent aesthetic acceptability and their comfort.

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