STUDY OF RESISTANCE OF THE FIBERGLASS PONTICS ON EXTERNAL APPLIED FORCES

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This article presents the study on the behavior of fiber glass reinforced composite (FRC) when external forces, similar to those occurring during mastication, are applied. The tests were carried out on models closely reproducing the dental bridges. Several FRC fixed partial dentures (FDP) were placed on a number of identical dental models using dental adhesives, dental composites, both self-cured and light-cured. The variables were: the type and the position of the fiber glass, the height of the composite of the pontic, the width of the pontic, and the person who did the maneuvers. Continual and increased forces were applied, and the resistance of each FPD was analyzed. We noticed that the model with unidirectional PECVD glass fiber reinforcement placed in a hammock trajectory with respect the edentulous ridge resisted up to a force of 700 N, which is far higher than an average masticatory force (220-450 N).

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1. Introduction

Many studies in various fields showed the advantages of fiberglass reinforced composites over other types of materials; this is why FRC have recently begun to be used in dentistry [1-4]. Classical dental bridges are made of metal alloys, covered with dental porcelain or with composite or acrylic resin. One of the disadvantages of metal-based dental bridges is that in order to cover the inesthetic metal component a deeper preparation of the abutment tooth was needed, which implied the loss of valuable dental tissue [3]. This is why many dentists have chosen to use FRC FPDs, which allow minimal invasive preparations, with highly esthetic results [3]. The problems that most commonly occur in FRC restorations are the delamination of the veneering composite and the fracture of the FPD [4].

In [5], Vallittu studied the survival rates of resin bonded, glass fiber reinforced composite fixed partial dentures and found that glass fiber- reinforced FPDs may be a possible alternative to cast metal resin bonded FPDs. However, Pilo et al. show in [6] that the survival rate of FRC FPD over 5 years is 75%, lower compared to porcelain fused to metal FPD which is 95%.

The aim of this study was to measure the resistance of FRC FPDs placed on clinical case model when external forces are applied. The fibre glass restauration was fixed to the first right upper premolar and to the second right upper molar using inlay preparation on both teeth. In particular we wanted to optimize the pontic in order to limit the vertical elongation as much as

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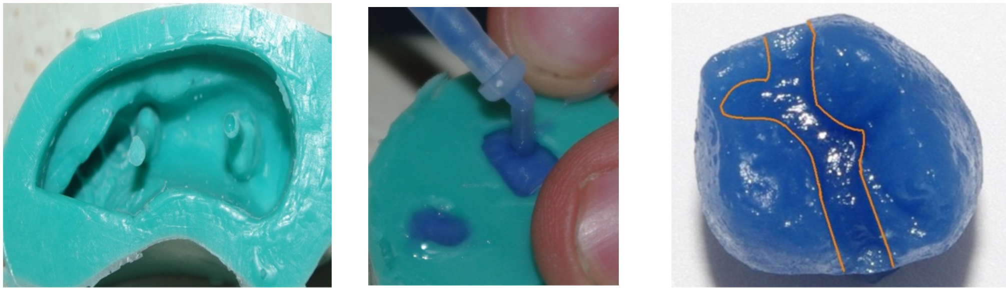
possible and to delay the first fracture in the pontic, up to forces far higher than the medium masticatory ones.

2. Experimental

In our study we used eight models which were identical from all points of view: anatomy, structure, material (class IV plaster and core material dental composite). The model was a half-arch case, with two missing teeth: the second right upper premolar and the first right upper molar. The edentation was created on the initial plaster model of a non edentulous patient, by cutting the two teeth mentioned above. Contrary to what Ozcan et al. did [7] preparing the inlays individually in each of the studied cases, we prepared the inlays on the initial model and then we reproduced all the teeth in one silicon template. The fact that the models were identical was also guaranteed by the template in which the half-arch was reproduced. See figure 1 a, b.



(a) *(b)* *(c)*

Fig. 1 (a) The template for the plaster basis (b) The template for the prepared teeth (c) Detail of the preparation of the molar.

Fig. 1 (c) is the model of a tooth made of blue dual-cure core material (used for all the models on which FRC FDPs were made by students). The orange lines indicate the limits of the inlay preparation on the occlusal surface of the molar. The teeth for the model on which the restoration was made by the instructor were injected in the same template using the same type of resin, only it was white (Fig. 2).

Fig. 2 The FRC FPD pontic model completed by the instructor.

The pre-impregnated glass fiber used for the eight FPDs was of two kinds: silanized multidirectional and PECVD (plasma enhanced composite vacuum deposition) unidirectional, both types of fibers being produced by Advanced Dental Materials, Czech Republic. The core material used for the teeth and for the pontic, as well as for the cementation of the inlays, was Luxacore (DMG, Germany). The plaster was class IV Ace Rock – Noritake. The adhesive used to cement the inlays was One Step Plus (BISCO).The differences between the eight models were: type of fiber (multi/unidirectional), trajectory of the fiber (hammock or straight over crest), the operator (instructor/one of the four students). All the models were completed in the same way: the dental adhesive was applied in the inlay preparations of the teeth and the core material was placed over the adhesive; then, the margins of the fiber strip were placed in the preparations and the whole structure was polymerized (Fig.3).

Fig. 3 Cementation of FRC pontic on the prepared teeth: polymerization of adhesive and composite using 430 nm light.

In the last phase, the upper part of the pontic was loaded with core material. A universal testing machine Zwick Z010 (Zwick/Roell) was used to apply a compressive load to the individual specimen, which was secured onto the duplicated stone model placed at the lower part of the testing machine The force was applied using a steel nose of 10 mm diameter and loading speed 2 mm/min on the central point of framework. (Fig.4)To prevent the bottom of the framework to come into contact with the stone, a layer of material underneath the bridge was removed. During loading, both the force and displacement of the loading nose were recorded After mechanical loading, all specimens were documented with camera Olympus C-300.

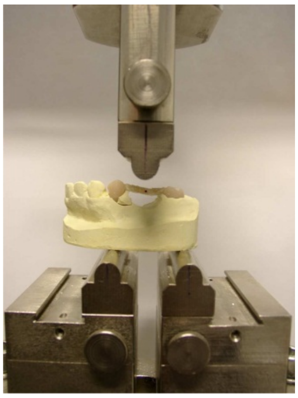


Fig.4. Stress testing machine.

Model number one was completed by the instructor using unidirectional PECVD fiber placed in a hammock trajectory. The maximum height of the pontic was 2.95 mm and the width (buccal-palatal dimension) was 4.04 mm.

Models two and three were completed in the same conditions as model number one, but by two different students (student 1 and student 2). The height of the pontic in model 2 was 3.16 millimeters and its buccal-palatal width 3.65 millimeters; for model 3 the same values were 3.42 and 4.76.

Model 4 was completed by student number three using unidirectional PECVD fiber but the trajectory of the fiber strip was straight over the crest. The height of the pontic was 3.42 and the buccal-palatal width 4.76.

In models five and six multidirectional silaned fiber was used, placed straight over the crest by student number four and student number two respectively. In model number five the height of the pontic was 2.91 mm and the width 3.76. In model 6 the height of the pontic was 2.65 and the width 3.92. Student number one worked also on model number seven, using multidirectional silaned fiber and applied a double height core material, obtaining a pontic height of 5.9 mm and a width of 3.71. In the last model, made by student number three, unidirectional

PECVD fiber was used, applying a double height core material, obtaining a height of the pontic of 6.66 mm and a width of 3.90. The fibers were placed in a hammock trajectory.

As mentioned before, the FPDs were completed by five different persons that is, one instructor and four students. As in dental medicine most elements are not identical we also tried to have several variables. The things that were constant (identical) were:

- The abutments and their preparation
- The cross-section of the fiber glass (both width and height of the fiber glass strip)

Because of the different ways in which the fiber and the composite were placed and because the models were completed by several operators, the width of the pontic varied between 3.65 mm and 4.76 mm and the height between 2.65 mm and 6.66 mm. The models were conceived in that way in order to:

-see how individual techniques influence the results (instructor vs. students). The models were identical, but the ways in which the fibers were adhesively fixed to the abutments and the ways in which the pontic was filled with composite, were different from one operator to another.

-test the best distribution of fiber. As mentioned above, the fibers were placed:

a) in a hammock position, that is, uniting the preparations on both abutments, following a curved trajectory;

b) in a straight over crest trajectory (starting from the inlay preparation, following the proximal margin of the tooth and then continuing with a 90 degree angle in a straight horizontal direction at a small distance from the edentulous crest).

-test the influence of the type of the fiber

-test the influence of the height of the composite over the fiber glass (models 7 and 8 had a double height core material compared to models 1 to 6).

3. Results and discussions

After completion, each of the eight FPDs was stress tested and the behavior was different. The parameters that we recorded for each of the eight models were:

1. Vertical elongation – which is clinically important, because it gives a hint on the traction that will be applied to the abutment teeth when chewing occurs on the pontic. Repeated traction eventually leads to impaired periodontal implantation of the abutment teeth.
2. The moment of the first crack – this gives a hint on microscopic degradation of the structure, especially because of small crack lines which highly increase water sorption.
3. The moment of the final crack – the breaking of the pontic; this makes the bridge clinically unusable.
4. The place in which the final fracture occurred

- Disjunction between the fiber strip and the abutment tooth
- Breaking of the fiber strip at the level of the pontic
- The fracture of the composite that was placed over the strip, suggesting the core material did not have enough compressive strength

Before presenting the results in detail, some considerations on the normal values of masticatory forces. Morenburg TR and Proschel PA [8] published the results of a clinical study in which they measured the forces occurring in mastication. Sensors were placed on the mandible and were connected to a computer. The mean masticatory force was 220 N and the maximum value was 450 N. Occlusal forces that occure during mastication are considerably lower than maximum bite forces. The functional forces generated during mastication have been measured using transducers incorporated within fixed and removable prostheses. Complete denture wearers have values that are one third to one fourth of those with a complete natural dentition. Patients with implant overdentures have a stronger maximum bite force than those with conventional complete dentures. Maximum axial loads of 70 to 150 N have been recorded during chewing and swallowing a variety of food. In most instances, chewing forces do not exceed 10 N. It is important to mention again that in our study the width and the height of the pontic (fiber plus composite) was different in each model (see table 1).

Table 1. Technical data of the study models.

No. model	Specimen thickness (mm)	Specimen width (mm)	Value of the force that produced the first crack (N)	Vertical elongation of the first crack (mm)	F_{max}(N)
1	2.95	4.04	180	0.29	420
2	3.16	3.65	150	0.36	350
3	3.42	4.76	220	0.34	440
4	3.42	4.76	140	0.14	380
5	2.91	3.76	100	0.29	120
6	2.65	3.92	85	0.34	170
7	5.90	3.71	400	0.33	420
8	6.66	3.90	700	0.28	1570

In model 1 the first fracture occured at a force of 180 N and the elongation in that moment was 0.29 mm. The force applied by the machine was continuous until an important fracture occured in that pontic. It is essential to know the force that can induce the first fracture, because the oral cavity is a wet environment, where several type of bacteria are present and a progressive infiltration of the pontic [9] is likely to start after the first fracture. The fractures can be produced not only by vertical and uniform forces, but also by non-constant forces from different directions.
When the force reached 420 N, the elongation was 0.86 mm; in that moment, the plaster surrounding the abutment of the first premolar broke and the distal part of the core material fractured (fig.5).

Fig. 5 (model 1) FPD with unidirectional PECVD fiber placed in a hammock trajectory – instructor.

In model 2 the first crack occured at 150 N, at a vertical elongation of 0.36 mm. As in all eight models, the machine kept applying a continuous force, inducing a certain number of small cracks, as the vertical elongation increased. The final fracture was on the proximal side of the composite (fig.6) at a force of 350 N and an elongation of 0.96 mm.

Fig. 6 (model 2) FPD unidirectional PECVD fiber placed in hammock trajectory – student 1.

The first crack in model 3 was at 220 N and a vertical elongation of 0.34 mm and eventually the composite broke at a junction with the distal tooth (fig.7) at 440 N and 1.76 mm elongation.

Fig. 7 (model 3) FPD unidirectional PECVD fiber placed in hammock trajectory – student 2.

In model 4 (fig.8) the first fracture occured at 140 N and 0.14 mm elongation and the final crack (delamination of the composite on the whole mesial half of the pontic) occured at 380 N and 0.88 mm elongation.

Fig. 8 (model 4) FPD unidirectional PECVD fiber placed in a straight over crest trajectory – student 3.

In models 5 and 6 the first cracks occured at 100N and 85 N respectively at 0.29mm and 0.34mm elongation. Final fractures occured at 120 N and 170 N respectively by delamination of the composite on the mesial half of the pontic (fig. 9 and 10).

Fig. 9 (model 5) FPD multidirectional silaned fiber, straight over crest – student 4.

Fig. 10 (model 6) FPD multidirectional silaned fiber, straight over crest – student 2.

In models 7 and 8 the results were far better. The main difference was the height of the composite on the pontic. The amount of composite used was almost double, uniformely applyed over the FRC. In model 7 (fig.11) the first crack occured at 400 N and 0. 33 mm elongation; at 420 N and 0.42 mm elongation the final crack occured in the distal part of the pontic.

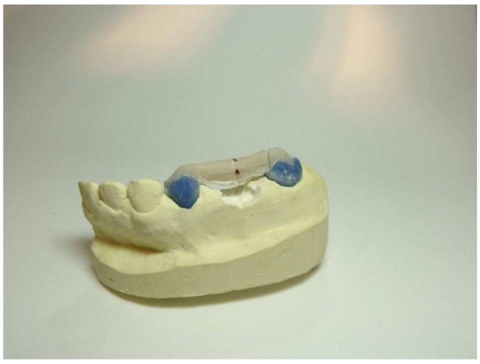


Fig. 11 (model 7) FPD multidirectional silaned fiber, double height core material hammock – student 1.

In model 8 the first crack occured at 700 N (much more than the mean masticatory force) and the relatively small elongation of 0.28 mm. Several other cracks occured as the force was increasing until 1570 N and 1.00 mm elongation, when the pontic broke (delamination) and both abutments broke also (fig.12).

Analysing the models, one can notice that the bridge with a thickness of 2.95 mm with a 4.04 width resisted a maximal force of 240 N, when a hammock distribution and unidirectional PECVD was used. In case of multiderectional fibers to reach the same force, the specimen thickness has to be close to 6 mm. Doubling the height of the core material can increase the mecanical resistance up to 4 times (comparing model 1 to 8). The lowest values were obtained with multidirectional fibers placed straight over the crest.

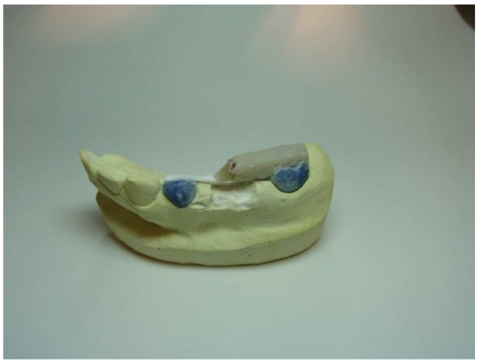


Fig. 12 (model 8) FPD unidirectional PECVD fiber placed in hammock trajectory double height core material – student 3.

The graph in figure 13 shows the behaviour (elongation and fractures) of each FPD when the force was applied.

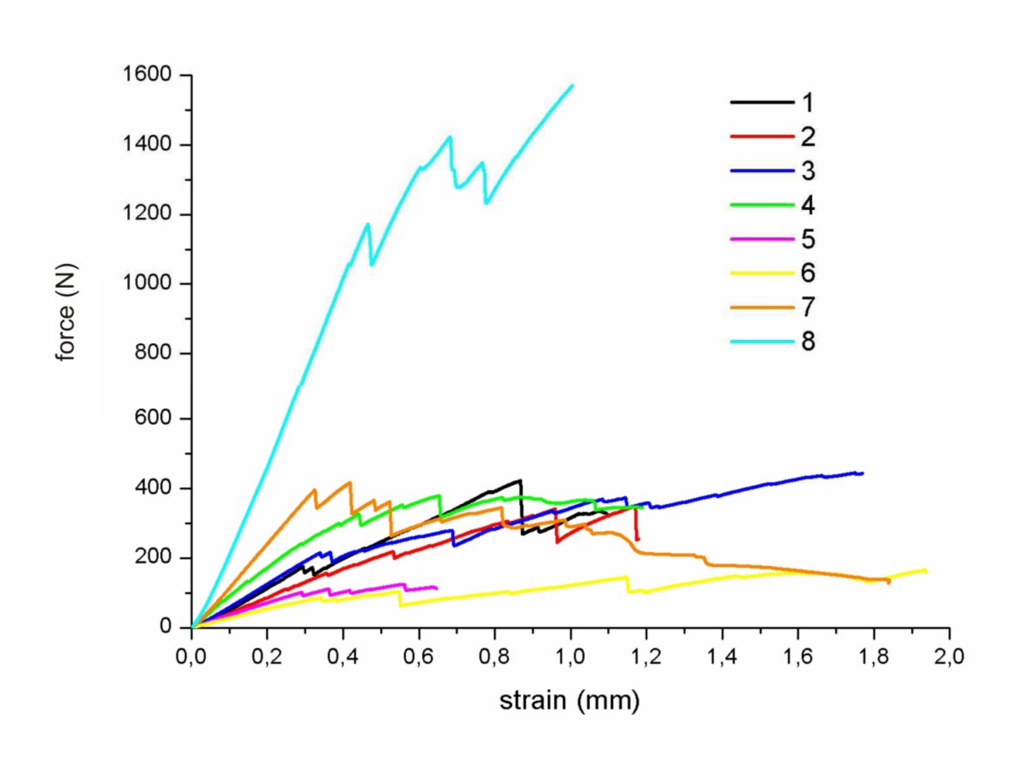


Fig.13 Stress behaviour. The samples 1 to 8 are as follows:
Model 1: hammock, unidirectional fiber PECVD, instructor
Model 2: hammock, unidirectional fiber PECVD, student 1
Model 3: hammock, unidirectional fiber PECVD, student 2
Model 4: straight over the crest, unidirectional fiber PECVD, student 3
Model 5: straight over the crest, multidirectional fibers silaned, student 4
Model 6 : straight over the crest, multidirectional fibers silaned, student 2
Model 7: hammock, multidirectional fibers silaned double height core material, student 1
Model 8: hammock, unidirectional fibers PECVD, double height core material,student 3

4. Conclusions

In the limits of this study we were able to conclude that fiberreinforced composite fixed partial dentures can be a good alternative to classical metal framework bridge, because mean masticatory forces are much lower than the maximal forces to which our models resisted. One should also note that the mean height of a pontic in a clinical case of a partial edentation is somewhere around 5 mm, which is close to the dimensions of models 7 and 8.

Specifically, two unit resin bonded bridge with inlay abutments preparation is strong enough to resist forces that normally occur during mastication and swallowing and they also resist maximal forces that have been recorded in removable denture sadles. Therefore FRC bridges may become an optimal metal-free restoration in the case in which the opposing teeth belong to a removable denture.

It has been demonstrated that the best results were obtained when the bridge was more than 6 mm height and the fibers were unidirectional PECVD. We could not determine which is the best trajectory of the fiber (hammock or straight over crest).

Intraoral placement of FRC-FPDs is relatively easy and with far less abutment preparation comparing to classical metal framework bridges. Unidirectional fibers PECVD show greater stress resistence than multidirectional fibers (silaned). This became apearant beacuse of the delamination related to multidirectional fibers, probably due to the sccissor like movement of the glass fiber during elongation.

The results seem to indicate that single unit FRC resin bonded bridge cemented on abutments with inlay preparations may become the ideal solution for single tooth replacement even in the posterior region.

The fact that the fiber glass reinforcement resisted well in all 8 models, even in forces three-four times greater than those occuring during mastication, leads us to suggest for further studies the use of fiber glass as a reinforcement for pre-sintered lythium disylicate, which has a far greater compressive strength than the composite core material.

References

[1] F. Heravi, S.M. Moazzami, S. Tahmasbi, Journal of Dentistry, **4** 53-58. (2007)
[2] S. Garoushi, L. Lassila, P. Vallittu, International Journal of Dentistry, **845420** 1-5. (2011)
[3] S. Garoushi and P. Vallittu, Libyan J. Med. **1** 73-82 (2006).
[4] V. Heumen, C. Kreulen, N. Creugers, Eur. J. Oral Sci. **117** 1-6 (2009).
[5] P. K. Valittu, J. Prosthet. Dent. **91** 241-246 (2004).
[6] R. Pilo, Z. Abu, A. Shmidt, Fiber-reinforced composite in fixed prosthontics, Refaut Hapeh Vehashinayim **27** 28-33 (2010).
[7] M. Ozcan, M. Breuklander, P. Vallittu, J. Prosthet. Dent. **93** 337-345 (2005) .
[8] T. Morenburg, P. Proschel, R. Vehashinayim, Int. J. Prosthodont. **15** 20-27 (2002).
[9] J. Tanner, P. Vallittu, E. Soderling, Biomaterials, **22** 1613-1618 (2001).