Load-Bearing Capacity of Direct Inlay-Retained Fibre-reinforced Composite Fixed Partial Dentures with Different Cross-Sectional Pontic Design

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The load-bearing capacity and fracture pattern of direct inlay-retained FRC FDPs with two different cross-sectional designs of the ponticwere tested. The aim of the study was to evaluate a new fibre disposition. Two types of composites, Filtek Bulk Fill Posterior Restorative and Filtek Z250 (3M/ESPE, St. Paul, MN, USA), and one braided polyethylene fibre, Construct (Kerr, USA) were used. The results of the study suggested that the new tested disposition of the fibres prevented in some extend the delamination of the composite on buccal and facial sides of the pontic and increased the load-bearing capacity of the bridges.

Keywords: inlay-retained FRC FPDs, cross-sectional pontic design,initial fracture load, fiber reinforced composite

In nowadays dentistry, the minimal invasive concept is the fundamental basis for any treatment approach [1]. From this perspective, the treatment of partial reduced edentulism might be a challenge. The persistence of any edentulism will lead to malocclusion and TMJ disorders which will complicate the long-term prognosis and the therapeutic solution.

The available means for replacing a missing tooth are: implant supported crowns (ISC) and fixed partial dentures (FPD). The materials used in these restorations are cast metal, ceramics and, more recently, composites.

The ISCs are reported to have a 5-year survival rate of 95.1% and a 10-year survival rate of 90%. However, the decision-making process for using of implant-supported prostheses is still, in certain cases of partial edentulism, an important topic of discussion [2]. Furthermore, multiple appointments, reluctance to surgery, temporary restorations, and costs make these procedures often inaccessible to many of our patients.

The traditional FDPs are reported to have a survival rate of 87.7% at 5 years and even 89.2% at 10-years in the particular situation of natural teeth [3]. As an alternative to metal infrastructure, glass-infiltrated alumina ceramics were introduced at the beginning of 1990s. The 10-year survival rate was reported to be 73.9% for 2-retainer FDPs and 94.4% for single-retainer FDPs [4]. Both need an important sacrifice of dental structures. The FPD are predominantly the full-coverage type, employing the sacrifice of 63 – 73% of coronal dental tissue in order to prepare for a full crown [5].

For the sake of the minimally invasive concept, the retainers have been modified and new designs for retainers were introduced (inlay, onlay and inlay-onlay) which require a less invasive preparation. In parallel with the reduction of the contact area, the chemical/micromechanical adhesion has been introduced and the luting and bonding systems were constantly improved. The inlay-retained fixed partial dentures are reported to have a 5-year survival rate of 57% and an8-year survival rate of 38% for IPS e.max Press (IvoclarVivadent AG) [6].

However, all these restorations have disadvantages like debonding, fracture and marginal leakage.

Many patients with partial reduced edentulism refuse the idea of sacrificing healthy teeth in order to restore the dental arch and others don't have the means to accept implants or ceramic resin-bonded restorations. In these cases, fibre-reinforced composite (FRC) bridges constitute a very suitable alternative contributing to the increase in life-quality. The patients can benefit from a system that is minimal invasive and accessible. However, the survival rate of FRC FPD is reported to be 73.4% at 4.5 years, the existing architecture of these bridges needing improvements [7].

Although fibre reinforced composite bridges can be currently regarded as niche restorations due to their specific and limited indications, they carry a great potential at affordable prices and could become the therapy of choice once the possibilities and limitations of these restorations are clearly defined.

The rich volume of clinical information on fibre reinforced composite bridges has enabled the utilization of a variety of systems which are different in method (direct/indirect/direct-indirect), materials (various fibres and composite types), design and structure, applied in different clinical situations.

Choosing adequate materials for a FRCB proves to be a difficult task, requiring extensive data and experience. The large choice of available materials and the wide range of properties make the task of selecting the right materials to be dependenton an extended study of properties and interactions.

Overall the reported advantages of these systems are[8-12]:

-aesthetic aspect comparable to ceramic, translucency;

-biocompatibility with oral tissues and inessential toxicity;

-no corrosiveness;

-preserving tooth substance, because the preparations are minimally invasive in contradistinction to metal-ceramic and all ceramic techniques;

-do not abrade or fracture the opposing teeth as ceramic does;

-good bonding properties: direct chemical bonding with no need of mechanical retention;

-less extensive work by the dental technician;

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-adequate mechanical properties;

-in the aspect of fatigue strength, there are reports of being stronger than typical cast metal alloys;

-potential for chair side fabrication, so there is no need for laboratory stages. In this way a prosthetic emergency (the absence of an incisor resulting from trauma) can be approached and the tooth can be replaced during a single visit;

-the pontic can be manufactured from the extracted teeth;

-ease of repair, when veneers fracture occurred.

The majority of the biomechanical studies performed on these restorations focus on the static testing of samples having ISO standard sizes. Also, most of the studies stop here. There are very few studies that use data resulted from sample testing in mathematical simulations or on physical models [13, 14]. Even fewer studies perform a clinical validation of the innovative technological solutions. At the same time, mechanical tests on bridges of these materials are insufficient, considering the wide variety of systems, aims and employed methods [15, 16].

The aim of the study was to evaluate theload-bearing capacity ofa new cross-sectional design for the pontic of fibre-reinforced composite bridges [17].

Experimental Part

Specimen preparation

40 extracted intact teeth (20 premolars and 20 molars) were cleaned by curettage, disinfected and then stored in saline solution at room temperature.Each of the 20 samples of FRC bridges was made on two teeth – premolar and molar - embedded in type IV dental stone (Picodent Z 260 v, PicodentGmBH, Germany), replicating the situation of one missing first molar with 10 mm mesio-distal length.

The bridges were retained by inlays in the class II cavities prepared on the distal and occlusal face of the premolar and on mesial and occlusal face of the molar. For the proximal cavity,the depth in cervical area was 1.5 mm, the length in buccal-oral direction was 3±0.5 mm and height, in cervico-occlusal direction, was 3±0.5 mm between the cervical and occlusal embrasures. For the occlusal cavity, the depth was 1.5 mm, the length in buccal-oral direction was 3 mm and in mesio-distal direction it was 5 mm. The distance between the abutment teeth was 10 mm.

Consequently, the bridges had the following dimensional parameters (fig. 1):

- 2 class II inlays:
- *thickness of 1.5 mm occlusal and 1,5 mm cervical*
- mezio-distal length = 5±0.5 mm
- buccal-oral width of the connector and vertical cavity = 3±0.5 mm
- cervico-occlusal height of connector = 3±0.5 mm
- 1 pontic:
- length = 10±0.5 mm
- height = 7±0.5 mm
- width = 8±0.5 mm

The FDPs were manufactured using two silicon molds (Registrado Clear, VOCO, Germany) in order to achieve the standard dimensions and the same aspect for the mucosal and occlusal sides. The occlusal side replicated the occlusal face of a first maxillary molar.

The inlay-retained FRC FDPs were made by using a 3mm braided polyethylene ribbon fibres (*Construct*, Kerr, USA), 2 types of composites (*Filtek Bulk Fill Posterior Restorative* 3M/ESPE, St. Paul, MN, USA and *Filtek Z250*, 3M/ESPE, St. Paul, MN, USA) and two types of adhesives (*Single Bond Universal Adhesive*, 3M ESPE, Germany and *Optibond All – In-One*, Kerr Italia, Italy).

Details of the materials used in this experimental study are given in table 1 and 2.

Two different cross-sectional designs of the pontic - parallel and adjacent - were used. In making the FPDs the Construct manufacturer's instructions were followed, as well the results of a previous study concerning cross-

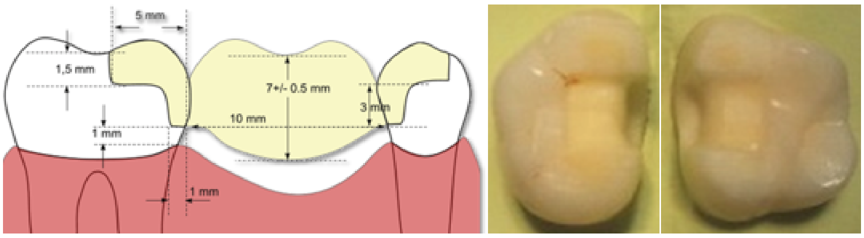

Fig. 1. Dimensional parameters of the bridges

Table 1
THE COMPOSITE RESINS USED FOR THE BRIDGES AND THEIR COMPOSITION

Brand	Manufacturer	Type	Matrix composition	Inorganic filler content	Lot No.
Filtek Bulk Fill Posterior Restorative	3M/ESPE, St. Paul, MN, USA	Bulk-fill	AUDMA, AFM DDDMA, UDMA	• 100 nm Ytterbium trifluoride (YbF_3) • non-agglomerated/non-aggregated 20nm silica filler and 4 to 11nm zirconia filler • aggregated zirconia/silica cluster filler (20nm silica and 4 to 11 m zirconia particles) • total inorganic filler loading 76.5% by weight (58.4% by volume)	N706090
Filtek Z250	3M/ESPE, St. Paul, MN, USA	Microhybrid	Bis-GMA, bis-EMA, UDMA	• Zirconia 78 wt%, 60 vol%, with a particle size range of 0.01to 3.5µ (average 0.6µ)	N805733
Filtek Bulk Fill Flow	3M/ESPE, St. Paul, MN, USA	Flowable	BisGMA, BisEMA(6), UDMA and Procrylat	• Zirconia/silica with a particle size range of 0.01to 3.5µ (average 0.6µ) • Ytterbium trifluoride particle size range of 0.1 to 5µ • Filler loading is 64.5% by weight (42.5% by volume)	N779563

AFM, addition-fragmentation monomers; AUDMA, aromatic dimethacrylate; Bis-GMA, bisphenol-A-glycidyldimethacrylate; bis-EMA, ethoxylated bisphenol-A-dimethacrylate; DDDMA, 1, 12-Dodecanediol dimethacrylate; UDMA, urethane dimethacrylate; wt%, weight percentage; vol%, volume percentage.

Table 2
MATERIALS USED FOR THE BRIDGE SAMPLES

Brand	Manufacturer	Type	Characteristics	Lot No.
Construct	Kerr Corporation, Orange, CA, USA	Braided fibre reinforcement ribbon - 3mm	Braided polyethylene fibres with ultra-high strength, silanated, cold plasma treated	5137532
Construct Resin	Dental Lab Products Kerr Corporation, Orange, USA	Wetting resin	Uncured methacrylate ester monomers, photoinitiators, inorganic fillers and stabilizing additives	5137527
Single Bond Universal Adhesive	3M ESPE, 3M Deutschland GmbH, Germany	Bonding agent	Self-etch dental adhesive	623865
Optibond All –In-One	Kerr Italia, Salerno, Italy	Bonding agent	Single component, self-etch dental adhesive	5457301
Registrado Clear	VOCO, Germany	Bite registration material	Transparent addition-curing silicone for bite registration, fast setting	1640090
Picodent Z 260 v	PicodentGmBH, Germany	Dental stone, type IV, extrahard	Calcium sulphate x 0.5 H_2O 95-100%	07-2017

sectional design of FRC systems [18]. In the respective study the best mechanical behaviour was recorded for a *U*-shaped disposition of the fibres, placed on the tension and lateral sides of the ISO 4049 (2 x 2 x 2.5 mm^3) bar samples.

According to the disposition of the fibres and the composite material used, 4 groups of FRC FPDs were made with 5 samples for each group (n = 5) (table 3).In the first group the bridges were made of Filtek Z250 with the two Construct fibres disposed straight and parallel, following the manufacturer indications. In the second group, the composite was also Filtek Z250, but the fibres were disposed respecting the *curved* method described by Waki et al. (2006) [19]and adjacent, supportingthe tension side and extending on the buccal and oral sides of the pontic (fig. 2).In the third group the Filteck Bulk Fill was used and the fibres were straight and parallel. In the fourth group the Filteck Bulk Fill was used with the adjacent and curved disposition of the fibres.The two different adhesives

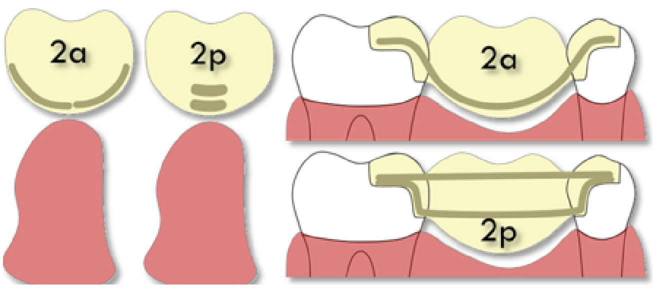

Fig. 2. Architecture of the fibres

(*Optibond All –In-One* and *Single Bond Universal Adhesive)* were randomly used for each sample.

In the first step of manufacturing of the bridges, the cervical mold for the mucosal side of the pontic was positioned between the teeth.Then the prepared cavities were sealed with the adhesive. Considering the same surface contact between the bridge and the teeth, for each of the two abutments a different adhesive was used. The light curing time was 20 s for each preparation. The photo-polymerization was done with a VALO Cordless LED curing light unit (Ultradent Products, USA), with 1100 mW/cm^2 power and 395-480 nm wavelength and its tip was positioned at 5 mm distance from the specimen. Approximately 0.2 mm of composite resin was applied on each box.

For the groups with the adjacent disposition of the fibres, an approximately 1.5 mm of composite resin was applied on the cervical mold, as the base of the pontic to the maximum buccal-oral diameter. Two Construct braid fibres were impregnated with Construct Resin (Dental Lab Products, Kerr Corporation, USA) and placed in the bed of the composite, in a curved manner and one besides the other, covering the mucosal side of the pontic and closely adapted to the prepared boxes. Each surface was light-cured for 40 s.

For the groups with the parallel disposition of the fibres, the first layer of the composite was placed up to the level of cervical limit of the proximal boxes. One Construct braid was placed straight between the abutments, closely fitted to the abutments cavities.The strap was light-cured for 40 seconds for each segment. The second strap was placed on another layer of composite in order to be placed at the level of the horizontal boxes. The second strap was light-cured for 40 sfor each segment.

For both groups the bridges were completed with the composite resin to restore the occlusal surfaces of the abutments and light-cured for 60 s. The occlusal surface of the pontic was completed using the transparent silicon mold replicating the morphology of a first maxillary molar. The surface was light-cured for 60 s. After removing the two molds, the bridges were light-cured for 60 sfor each surface. The dimensions of the bridges were checked, finished and polished using Kerr Composite Finishing System.

Table 3
THE FOUR GROUPS' CHARACTERISTICS

		No. of fibres	Design	Groups	No. of samples
Construct (C)	***Filteck Z250 (Fz)***	2	parallel (p)	CFz2p	5
		2	adjacent (a)	CFz2a	5
	Filteck Bulk Fill (Fb)	2	parallel (p)	CFb2p	5
		2	adjacent (a)	CFb2a	5

The samples were stored in distilled water for 24 hours before testing.

Mechanical testing

The specimens were subjected to three-point bending test using a universal testing machine WDW-5CE type with a maximum load of 25kN. The specimens have been tested by static short duration loads at a cross-head speed of 0.1mm/min, at room temperature and in normal humidity conditions. The load was applied at the middle of the test specimen perpendicular to the long axis, with a rounded-ended striker of 6 mm diameter. Loading was removed when either sample showed catastrophic rupture or a negative slope of load vs. displacement was recorded after the peak load, with the load values dropping continually below 85% of the peak load [20].

The diagram of the force variation in relation with time and deformation was obtained; the initial fracture force, maximum force, stress at the connector levels and initial and final deformation were assessed.

The stress at the connectors level was [21]:

$$\sigma = \frac{M}{W_z}$$

σ = stress in the specimen

M = bending moment

W_z = modulus axial

The specimen was considered as a double embedded beam.

The indeterminacy of the beam was lifted up and the value of the bending moment in the junction was assessed as:

$$M = \frac{F\ x\ l}{8}$$

F = initial / maximum fracture load

l = length of the pontic (distance between the junctions)

$$W_z = \frac{b\ x\ h^2}{6}$$

b = width of the pontic

h = height of the pontic

Statistical method

Mean data values and SDs were calculated for initial and final load fracture, initial and final deformation of the pontic and initial and final fracture stress in the junctions. The initial flexural load corresponds to the first cracks appeared in the sample, which are usually initiated in the junctions part of the bridges. The final flexural load corresponds to the peak load, which for some samples coincides with the catastrophic failure.

Two-way analysis of variance (ANOVA) and Tukey post hoc multiple comparisons test were used to determine the significance of the difference between mean values of recorded flexural load, deformations and initial and final fractures stress in the junctions for each main category. The independent factors were the composite material and the cross-sectional pontic design. The dependent factors were initial and final fracture load, initial and maximal deformations and initial and maximal stress in the junctions.All tests were performed at a significance level of $\alpha = 0.05$.

Results and discussions

All the samples demonstrated a perfect elastic behaviour, as the diagrams showed.

Failure analyses revealed that the initiation of the fracture was at the level of the connectors, between the pontic and the retainers, these zones proving to be the weakest points of the bridges. Two different failure patterns were noticed: (1) from the cervical aspect of the connectors, the fracture is propagated oblique, in the mass of the composite, to the middle of the occlusal face, through the buccal and oral faces, with or without delamination of the composite from these faces – groups CFz2p and CFb2p; (2) from the connectors, the fracture is propagated to the occlusal face, preserving the buccal and oral faces; new fractures appeared, in the compression area, around the loading point, interesting the cusps, above the highest position of the fibres (fig. 3 and fig. 4).

For all the samples the moment of total destruction of the bridges was delayed related to the moment of initial fracture, supporting the importance of the fibres in sustaining the mechanics of the restoration. This allows the intraoral maintenance of the bridge even after the fissure appearance, which from esthetical and psychological point of view is very important.

Fig. 3. Fracture pattern for parallel design of the fibres

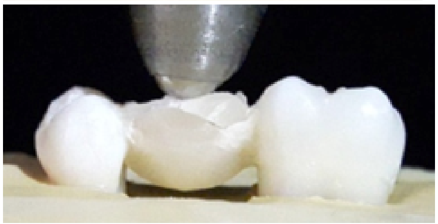

Fig. 4. Fracture pattern for adjacent design of the fibres

None of the samples showed any debonding of the dental bridges from the abutments.

Significant differences ($p < 0.05$)for initial fracture forces values were found between the groups with adjacent disposition (CFb2a = 1565.2 ± 126.5 N; CFz2a = 1380.8 ± 29 N) and parallel disposition of the fibres (CFb2p = 1087.7 ± 133.3 N; CFz2p = 1212.8 ± 126.8 N) (table 4). For the same cross-sectional design, there are no significant differences for the type of the composite that was used. But two-way ANOVA test showed that the combinations between the fibres disposition and the composites are relevant andthe best results are in the case of CFb2a (table 5 and table 6).

The maximum fracture recorded loads were due to the architecture of the fibres and not to the composite type (table 7). The maximum mean values were recorded for

Table4

MEAN VALUES RECORDED FOR INITIAL FRACTURE LOADAND MAXIMUM LOAD (N)

	Initial fracture load				Maximum load			
	CFb2p	CFb2a	CFz2p	CFz2a	CFb2p	CFb2a	CFz2p	CFz2a
Average	1.087,7	1.565,2	1.212,8	1.380,8	1.291,4	1.574,7	1.504,7	1.633,5
Std. Dev.	133,3	126,5	126,8	29,0	17,7	141,5	47,3	44,8
Err.max	116,8	110,8	111,2	25,4	15,5	124,0	41,5	39,3
Max	1.204,5	1.676,0	1.324,0	1.406,2	1.307,0	1.698,8	1.546,2	1.672,8
Min	970,9	1.454,4	1.101,7	1.355,4	1.275,9	1.450,7	1.463,3	1.594,3

Table 5
TWO-WAY ANALYSIS OF VARIANCE INITIAL FRACTURE LOAD (KN)

SUMMARY	2p	2a	Total
Fb			
Count	5	5	10
Sum	5,4385	7,826	13,2645
Average	1,0877	1,5652	1,32645
Variance	0,017756	0,015992	0,078334
Fz			
Count	5	5	10
Sum	6,0642	6,9039	12,9681
Average	1,21284	1,38078	1,29681
Variance	0,016081	0,00084	0,015355

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	0,004393	1	0,004393	0,346774	0,564167	4,493998
Columns	0,520741	1	0,520741	41,10952	8,61E-06	4,493998
Interaction	0,119784	1	0,119784	9,456281	0,007248	4,493998
Within	0,202675	16	0,012667			
Total	0,847592	19				

Table 6
TUKEY'S MULTIPLE COMPARISON TEST (TUKEY'S HSD) - PAIR-WAYS COMPARISON BETWEEN MEANS FOR INITIAL FRACTURE LOAD. STATISTICALLY SIGNIFICANT DIFFERENCES ARE HIGH-LIGHTED ($p<0.05$)

Groups		CFb2p	CFb2a	CFz2p	CFz2a
	Average	1,0877	1,5652	1,21284	1,38078
CFb2p	1,0877				
CFb2a	1,5652	0,4775			
CFz2p	1,21284	0,12514	0,35236		
CFz2a	1,38078	0,29308	0,18442	0,16794	

Table 7
TWO-WAY ANALYSIS OF VARIANCE MAXIMUM LOAD (KN)

SUMMARY	2p	2a	Total
Fb			
Count	5	5	10
Sum	6,4572	7,8737	14,3309
Average	1,29144	1,57474	1,43309
Variance	0,000314	0,020026	0,031334
Fz			
Count	5	5	10
Sum	6,5062	8,1676	14,6738
Average	1,30124	1,63352	1,46738
Variance	0,012204	0,002007	0,036985

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	0,005879	1	0,005879	0,680616	0,421505	4,493998
Columns	0,473673	1	0,473673	54,8373	1,49E-06	4,493998
Interaction	0,002999	1	0,002999	0,347172	0,563946	4,493998
Within	0,138205	16	0,008638			
Total	0,620756	19				

CFz2a group (1633.5 ± 44.8 N) (table 4), but the combination between the design of the pontic and the composite type was not statistical relevant (table 7).

The maximum stress appeared at the initial fracture force at the level of the connector was recorded in the case of CFb2a group (420.6±33.5 N) (table 8). Both, the fibres disposition and the type of composite are relevant for this situation (table 9, table 10).

The final stress in the connectors is maximum for the groups with the adjacent fibresdisposition, independent of the composite type (table 11).

The maximum initial deformation, recorded at the moment of the fracture initiation, appeared for the adjacent fibres groups (CFb2a = 0.4845 ± 0.0322 mm, CFz2a = 0.4985 ± 0.0461 mm) (table 12). If in this case, there is no significant difference between these two groups (table 14), in the case of the final deformation, the difference is significant (CFb2a = 0.6076 ± 0.0171 mm, CFz2a = 0.8816 ± 0.0583 mm) (table 16).

Overall the results suggested a significant difference between the load-bearing capacities of the bridges with adjacent fibres cross-sectional design and of those with parallel disposition of the fibres. This difference might become even more evident in the case of higher pointed cusps, when the fibres couldbetter supportthe composite that is transversally stressedby the horizontal component of the forces decomposed on the cuspslopes. The adjacent

	σinitial				σfinal			
	CFb2p	CFb2a	CFz2p	CFz2a	CFb2p	CFb2a	CFz2p	CFz2a
Average	289,5	420,6	327,8	359,8	343,7	423,1	351,7	426,0
Std. Dev.	36,3	33,5	37,9	21,7	7,8	37,6	35,6	33,2
Err.max	31,8	29,4	33,3	19,0	6,8	33,0	31,2	29,1
Max	321,3	450,0	361,0	378,8	350,5	456,1	382,9	455,1
Min	257,7	391,2	294,5	340,7	336,8	390,2	320,5	396,9

Table 8
MEAN VALUES FOR INITIAL JUNCTIONAL STRESS AND FINAL JUNCTIONAL STRESS (N/mm^2)

Table 9
TWO-WAY ANALYSIS OF VARIANCE INITIAL STRESS IN THE CONNECTOR (KN)

SUMMARY	2p	2a	Total
Fb			
Count	5	5	10
Sum	1,447266	2,102887	3,550153
Average	0,289453	0,420577	0,355015
Variance	0,001316	0,001124	0,005861
Fz			
Count	5	5	10
Sum	1,638768	1,798751	3,437519
Average	0,327754	0,35975	0,343752
Variance	0,001439	0,000471	0,001134

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	0,000634	1	0,000634	0,583185	0,456181	4,493998
Columns	0,03326	1	0,03326	30,5792	4,57E-05	4,493998
Interaction	0,012283	1	0,012283	11,29264	0,003979	4,493998
Within	0,017403	16	0,001088			
Total	0,063581	19				

disposition of the fibres might prevent in some extend the delamination of the composite on buccal and facial sides of the pontic (fig. 5). To the best of our knowledge, this type of cross-sectional design was never mentioned in the literature. It is more suitable for braided polyethylene fibres types which are easily spreadable, covering a bigger

Table 10
TUKEY'S MULTIPLE COMPARISON TEST (TUKEY'S HSD) - PAIR-WAYS COMPARISON BETWEEN MEANS FOR NORMAL STRESS IN THE CONNECTOR FOR THE INITIAL FRACTURE FORCE. STATISTICALLY SIGNIFICANT DIFFERENCES ARE HIGH-LIGHTED ($p<0,05$)

Groups		CFb2p	CFb2a	CFz2p	CFz2a
	Average	0,2895	0,4206	0,3278	0,3598
CFb2p	0,2895				
CFb2a	0,4206	0,131124			
CFz2p	0,3278	0,0383	0,092824		
CFz2a	0,3598	0,070297	0,060827	0,031997	

SUMMARY	2p	2a	Total			
Fb						
Count	5	5	10			
Sum	1,718356	2,1157	3,834056			
Average	0,343671	0,42314	0,383406			
Variance	6,06E-05	0,001414	0,00241			
Fz						
Count	5	5	10			
Sum	1,758602	2,130069	3,888671			
Average	0,35172	0,426014	0,388867			
Variance	0,001268	0,001104	0,002587			
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	0,000149	1	0,000149	0,155095	0,698912	4,493998
Columns	0,029554	1	0,029554	30,73346	4,45E-05	4,493998
Interaction	3,35E-05	1	3,35E-05	0,034815	0,854329	4,493998
Within	0,015386	16	0,000962			
Total	0,045122	19				

Table 11
TWO-WAY ANALYSIS OF VARIANCE FINAL STRESS IN THE CONNECTOR (MM)

	Initial deformation				Final deformation			
	CFb2p	CFb2a	CFz2p	CFz2a	CFb2p	CFb2a	CFz2p	CFz2a
Average	0,2494	0,4845	0,3493	0,4985	0,5157	0,6076	0,5164	0,8816
Std. Dev.	0,0311	0,0311	0,0618	0,0461	0,0652	0,0171	0,0955	0,0583
Err.max	0,0272	0,0272	0,0542	0,0404	0,0571	0,0150	0,0837	0,0511
Max	0,2766	0,5117	0,4035	0,5388	0,5728	0,6227	0,6001	0,9326
Min	0,2221	0,4572	0,2951	0,4581	0,4586	0,5926	0,4326	0,8305

Table 12
MEAN VALUES RECORDED FOR INITIAL DEFORMATION AND FINAL DEFORMATION (MM)

Table 13
TWO-WAY ANALYSIS OF VARIANCE INITIAL DEFORMATION (MM)

SUMMARY	2p	2a	Total			
Fb						
Count	5	5	10			
Sum	1,2468	2,4223	3,6691			
Average	0,24936	0,48446	0,36691			
Variance	0,000966	0,000965	0,016212			
Fz						
Count	5	5	10			
Sum	1,7465	2,4923	4,2388			
Average	0,3493	0,49846	0,42388			
Variance	0,003825	0,002123	0,008824			
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	0,016228	1	0,016228	8,238201	0,011106	4,493998
Columns	0,18457	1	0,18457	93,698	4,31E-08	4,493998
Interaction	0,009232	1	0,009232	4,686738	0,045858	4,493998
Within	0,031517	16	0,00197			
Total	0,241547	19				

Table 14
TUKEY'S MULTIPLE COMPARISON TEST (TUKEY'S HSD) - PAIR-WAYS COMPARISON BETWEEN MEANS FOR INITIAL DEFORMATION. STATISTICALLY SIGNIFICANT DIFFERENCES ARE HIGH-LIGHTED ($p<0.05$)

Groups		CFb2p	CFb2a	CFz2p	CFz2a
	Average	0,24936	0,48446	0,3493	0,49846
CFb2p	0,24936				
CFb2a	0,48446	0,2351			
CFz2p	0,3493	0,09994	0,13516		
CFz2a	0,49846	0,2491	0,014	0,14916	

Table 15
TWO-WAY ANALYSIS OF VARIANCE FINAL DEFORMATION (MM)

SUMMARY	2p	2a	Total			
Fb						
Count	5	5	10			
Sum	2,5785	3,0382	5,6167			
Average	0,5157	0,60764	0,56167			
Variance	0,004248	0,000294	0,004367			
Fz						
Count	5	5	10			
Sum	2,5818	4,4078	6,9896			
Average	0,51636	0,88156	0,69896			
Variance	0,009128	0,003397	0,042614			
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	0,094243	1	0,094243	22,08757	0,000241	4,493998
Columns	0,261221	1	0,261221	61,22214	7,39E-07	4,493998
Interaction	0,093339	1	0,093339	21,87571	0,000252	4,493998
Within	0,068268	16	0,004267			
Total	0,517071	19				

Table 16
TUKEY'S MULTIPLE COMPARISON TEST (TUKEY'S HSD) - PAIR-WAYS COMPARISON BETWEEN MEANS FOR FINAL DEFORMATION. STATISTICALLY SIGNIFICANT DIFFERENCES ARE HIGH-LIGHTED ($p<0.05$)

Groups		CFb2p	CFb2a	CFz2p	CFz2a
	Average	0,5157	0,60764	0,51636	0,88156
CFb2p	0,5157				
CFb2a	0,60764	0,09194			
CFz2p	0,51636	0,00066	0,09128		
CFz2a	0,88156	0,36586	0,27392	0,3652	

surface of tensile surface of the pontic. This architecture extends the results obtained in a previous study on ISO type bar specimens [18].

In some regards, the testing of the specimens in this study can be considered as extreme. The concentration of the forces in one loading-point and the absence of physiological periodontal resilience are among the factors altering the results. Intra-orally, through a distributed dispersion of the occlusal forces along the dental arch, the fracture pattern might be modified. Even in this context, the adjacent disposition of the fibres in the pontic should

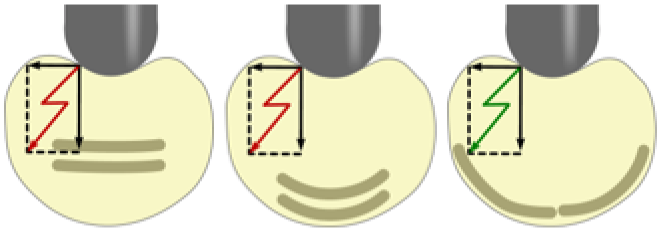

Fig. 5. Fracture pattern according to the fibres disposition

improve the mechanical behaviour to the transversal forces, frequently encountered in oral conditions.

Clinically, the dental restorations are subjected to masticatory forces ranging between 500 and 900 N in the molar region [22], but according to DIN standard, the FDPs have to withstand forces which exceed 1000N in static fractures tests [23-25]. The tested samples in this study withstood forces higher than 1300 N for the adjacent disposition of the fibres, which make them suitable for clinical application.The periodontal resilience might allow even a superior load-bearing capacity of the FRCBs, without deformation, except in case of occlusal trauma.

One important factor contributing to survival-rate of FRCBs is the inter-abutment distance, related to the amplitude of the pontic. A reduction of 25 to 35% of the fracture strength was recorded in case of increasing the pontic from 7 to 11 mm in the case of inlay-retained FRCBs[26].The different specimen dimension is one of the many factors which make that the comparison of other studies results to be difficult or inconsistent. Other factors are: methodology, employed materials, fibre thickness, location and orientation [25, 27 - 29].

An interesting finding of this study is that there were no failures in the form of debonding proving the existence of a strong adhesive interface able to resist the occlusal forces.

The relative small sample size might be the most important limitation of this study. It could be reason for not finding significant differences between the two tested composites – Filteck Z250 and Filteck Bulk Fill.

Another limitation of this study is that the specimens were not subjected to thermocycling and fatigue testing with water immersion, as supplementary conditions for estimating the mechanical behaviour in vivo conditions [30-32].

Conclusions

Within the limitations of this in vitro study, the following conclusions could be drawn:

Both parallel and adjacent cross-sectional design proved to withstand forces higher than 1000 N until the initiation of the fracture.

The load-bearing capacity of the bridges with adjacent fibre disposition increased comparing with those with parallel disposition of the reinforcing fibres.

The adjacent dispositionof the braided polyethylene fibresat the pontic tensile surface might prevent the delamination of the composite on buccal and facial sides of the pontic.

Acknowledgement: This research is financed by the Grigore T. Popa University of Medicine and Pharmacy Iasi stipulated by the contract 30880/30.12.2014.

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Manuscript received: 28. 07. 2016