

Glass fibre reinforced versus multistranded bonded orthodontic retainers: a 2 year prospective multi-centre study

Michel P. E. Tacken*, Jan Cosyn**,***, Peter De Wilde*, Johan Aerts*, Elke Govaerts* and Bart Vande Vannet*

Departments of *Orthodontics and **Periodontology, Dental Medicine, Free University of Brussels (VUB), and ***Department of Periodontology and Oral Implantology, School of Dental Medicine, University of Ghent, Belgium

SUMMARY The objective of this study was to compare glass fibre reinforced (GFR) with multistranded bonded orthodontic retainers in terms of success rate and periodontal implications.

A 2 year parallel study was conducted of 184 patients scheduled to receive bonded retainers in the upper and lower anterior segments. In three centres, the patients (mean age 14 years; 90 males and 94 females) were sequentially assigned to receive GFR retainers containing 500 unidirectional glass fibres (GFR500), 1000 unidirectional glass fibres (GFR1000), or multistranded retainers (gold standard). Retainer failures and periodontal conditions were monitored every 6 months. In a control group of 90 subjects without retainers, periodontal conditions were examined (negative control). Of the 274 recruited patients, 15 dropped out during the 2 year study period. Kaplan–Meier plots were drawn to assess survival of the different retainers. The Mantel–Cox log-rank test was used to identify significant differences in survival functions among the groups. Repeated measures analysis of variance and appropriate *post hoc* tests were adopted to evaluate periodontal conditions over time.

GFR retainers showed unacceptably high failure rates in comparison with multistranded retainers (51 versus 12 per cent). The most significant periodontal conditions were found in patients with GFR retainers with no significant differences between the GFR500 and the GFR1000 group for any parameter at any time point. Subjects without retainers showed significantly lower levels of gingival inflammation and plaque accumulation when compared with patients in any retainer group.

Multistranded retainers should remain the gold standard for orthodontic retention, although periodontal complications are common. The use of GFR retainers should be discouraged in daily practice.

Introduction

Orthodontic treatment results are potentially unstable and, therefore, often require retention in the anterior segment of the upper and lower jaw. Contemporary retaining strategies basically include removable and fixed retainers. As the former depend on patient compliance, fixed retainers are usually preferred. Zachrisson (1983) introduced the multistranded bonded lingual retainer. Apart from variations in wire types, diameters, and bonding procedures, this type of retainer has become the gold standard (Bearn, 1995). Multistranded bonded lingual retainers show success rates of between 60 and 95 per cent in the long-term, with most failures in the maxilla during the first year of function (Dahl and Zachrisson, 1991; Andrén *et al.*, 1998). Studies have indicated acceptable compatibility of metal-bonded retainers with periodontal health (Årtun, 1984; Årtun *et al.*, 1987, 1997; Heier *et al.*, 1997; Booth *et al.*, 2008). Limitations, however, include aesthetics and the fact that they cannot be used in patients with a nickel allergy. Therefore, alternatives have been developed such as polyethylene ribbon-reinforced retainers and glass fibre reinforced (GFR) retainers. Case reports have been published

on the latter (Geserick *et al.*, 2004; Brauchli *et al.*, 2006); however, no large-scale long-term study has been undertaken documenting the success rate and periodontal implications.

The objective of this study was to compare GFR with multistranded bonded orthodontic retainers in terms of success rate and periodontal implications.

Subjects and methods

The study protocol was approved by the Ethics Committee of the University Hospital of Brussels (UZ Brussels).

Experimental design

One hundred and eighty-four adolescents (mean age 14 years; 90 males and 94 females) who were scheduled to receive bonded lingual retainers (from lateral incisor to lateral incisor in the upper jaw and from canine to canine in the lower jaw) were enrolled for a parallel study. All patients had been orthodontically treated with fixed appliances in one of three private practices.

The inclusion criteria were good general health, correct dental alignment, a Class I relationship with an overbite/overjet between 1 and 3 mm, and the need for permanent orthodontic retention in the upper and lower anterior segments. The exclusion criteria were periodontal disease, advanced dental abrasion/attrition/erosion, and bruxism.

After having obtained written informed consent, the patients were sequentially assigned to either a GFR500 retainer group ($n = 45$), a GFR1000 retainer group ($n = 48$), or a multistranded wire group ($n = 91$). Thus, in the first patient GFR500 retainers were placed, in the second GFR1000 retainers, in the third and the fourth multistrand retainers, and so on. This type of randomization ensured comparable frequency distributions of the groups among the centres. In all centres, at least 61 patients were enrolled. In addition, 90 un-treated subjects were recruited at a high school and examined by one clinician (MPET) at the end of the study.

The subjects in this control group were enrolled on the basis of the same selection criteria as the treated patients except for the need for permanent retention. All subjects ($n = 274$) completed a questionnaire on daily home care prior to the start of the study. Table 1 shows the demographic details and data on oral hygiene habits. All groups were compatible in terms of gender, age, and pre-study oral hygiene habits.

Bonding procedures

All retainers were bonded by three experienced clinicians (BVV, PDW, JA) at the different centres using a standardized protocol. For all types, the same etch gel (35 per cent phosphoric acid; Ortho Organizers®, San Marcos, California, USA), bonding system (Excite®, Vivadent, Schaan, Liechtenstein), and flowable composite (Tetric flow®, Vivadent) were used (Elaut *et al.*, 2002). Retainers in the lower jaw were positioned half way up the lingual crown surface of the teeth avoiding contact with papillae; retainers in the upper jaw were placed more apically avoiding occlusal interference.

Patients allocated to the GFR500 group received retainers containing 500 unidirectional glass fibres (EverStick®Ortho 500, Stick Tech Ltd, Turku, Finland), which had been specifically manufactured for this study, while those in the GFR1000 group received commercially available retainers containing 1000 unidirectional glass fibres (EverStick®Ortho

1000, Stick Tech Ltd). The rationale for including two GFR retainer groups was related to the hypothesis that a thinner retainer would result in less plaque accumulation and therefore superior periodontal conditions.

All fibres were cut to the appropriate length, which had been measured on plaster casts using dental floss. Wedges were then placed interdentally to avoid interproximal contamination and ensure good access for subsequent cleaning. Lingual tooth surfaces were cleaned, sandblasted (Al_2O_3 50 μ), and etched for 30 seconds. The teeth were air-dried and isolated using saliva ejectors and cotton rolls. The bonding agent was applied on all teeth, light cured with a light emitting diode (Ortholux; 3M Unitek, Monrovia, California, USA) for 5 seconds per tooth, followed by the application of the flowable composite. Light curing was carried out for each tooth for 10 seconds after the retainer had been correctly adjusted. The use of a wide instrument (Stickstepper®, Stick Tech Ltd) prevented premature curing at neighbouring teeth. The procedure was repeated tooth by tooth followed by the application of a thin layer of flowable composite covering the glass fibres (Figure 1).

In the multistranded retainer group, the subjects had six stranded 0.0215 inch coaxial wire (Ortho Organizers®) used for retention, which had been constructed on plaster casts. Tooth conditioning, isolation, and application/curing of the bonding agent was carried out in the same way as described for the GFR retainers. Subsequently, the coaxial wire was placed on to the teeth using a putty holder and flowable composite was used to attach the wire to the upper lateral incisors or lower canines. After removal of the holder, the same procedure was repeated for the other teeth (Figure 2).

Each bonding procedure was completed by giving oral hygiene instructions with emphasis on interdental cleaning using dental floss (Superfloss®, Oral-B Laboratories, Diegem, Belgium).

Examination criteria

The following clinical parameters were recorded by the same calibrated clinician (MPET) at the 6, 12, 18, and 24 month follow-up:

1. Success rate. A retainer was considered successful when it remained intact over the 2 year study period. When failure

Table 1 Demographic details and oral hygiene habits prior to the start of the study of the four groups.

Group	Patients	Males	Females	Age, Mean (SD)	Daily use of an electric brush (%)	Use of interdental aids $\geq 1 \times$ /week (%)
GFR500	45	23	22	14.8 (1.3)	38	76
GFR1000	48	23	25	14.6 (2.7)	30	65
MR	91	44	47	15.0 (1.3)	35	70
Control	90	45	45	14.1 (1.1)	31	67

Glass fibre reinforced bonded orthodontic retainers containing 500 unidirectional fibres (GFR500), 1000 unidirectional fibres (GFR1000), multistranded bonded orthodontic retainers (MR), and the control group (control).



Figure 1 Glass fibre reinforced bonded orthodontic retainer in the upper (a) and lower (b) jaw.

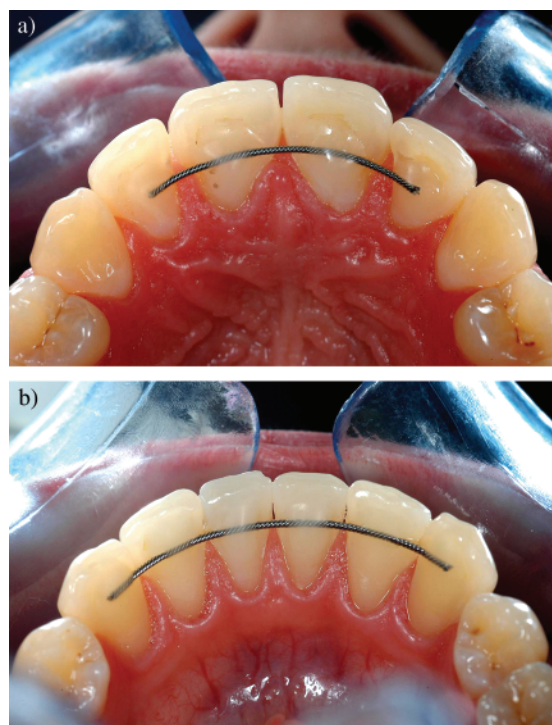


Figure 2 Multistranded bonded orthodontic retainer in the upper (a) and lower (b) jaw.

occurred, the time from initial bonding until failure (time to event) was recorded. For each failure, a distinction was made between detached and broken retainers.

2. Modified gingival index (MGI) (Lobene *et al.*, 1986). Gingival inflammation was measured at three sites per tooth (mesial, central, and distal) and scored as follows: absence of inflammation (0), part of gingival unit mild inflammation (1), complete gingival unit mild inflammation (2), moderate inflammation (3), and severe inflammation (4).
3. Bleeding on Probing (BOP) (Cosyn and Verelst, 2006). Gingival bleeding tendency was measured at three sites per tooth (mesial, central, and distal) using a manual probe (CP 15 UNC, Hu-Friedy®, Chicago, Illinois, USA). The bleeding score was registered after 15 seconds: no bleeding (0), point-bleeding (1), and abundant bleeding (2).
4. Plaque index (PI) (Quigley and Hein, 1962). Plaque levels were measured at three sites per tooth (mesial, central, and distal) following plaque disclosure using red Rondell Disclosing Pellets (Svenska®, Stockholm, Sweden). The scores ranged from 0 to 5: no plaque (0), spots of plaque at the cervical margin (1), thin continuous band of plaque at the cervical margin (2), gingival third of tooth surface covered with plaque (3), two-thirds of tooth surface covered with plaque (4), more than two-thirds of tooth surface covered with plaque (5).

At each assessment, oral hygiene instruction was reinforced and plaque/calculus was mechanically removed. Finally, all teeth were polished (Nupro® Fine, Ash, Denstply, York, UK). These procedures were performed by the same clinician in all patients (MPET).

Calibration session

To optimize the reliability of the results, the investigator who carried out the clinical assessments was calibrated prior to the start of the study. Fifteen patients with bonded lingual retainers were enrolled for this purpose. Duplicate measurements of 180 anterior teeth ($n = 540$) for the MGI and PI were collected over a time interval of 2 hours.

Statistical analysis

Kaplan–Meier survival analysis was performed to monitor retainer failures over time. The Mantel–Cox log-rank test was used to identify significant differences in survival functions among the groups. Retainers in the maxilla were separately analysed from those in the mandible. The Mantel–Cox log-rank test was also adopted to determine centre-related differences in survival functions for the different types of retainers. Significant differences in the proportion of broken or detached retainer failures among the groups were analysed using Fisher's exact test.

For all periodontal parameters, the mean values and standard deviations were calculated per subject and per visit. Since ordinal-scaled variables become interval scaled as such, and because the data conformed to a normal distribution

as evaluated by means of the one-sample Kolmogorov–Smirnov test, parametric data analysis was performed. The periodontal changes over time within each group (within group comparison) and the impact of the treatment strategy on these parameters (between group comparison) were examined by means of repeated measures analysis of variance. Treatment strategy, time, and their interaction were modelled as fixed factors and the patient as a random factor with MGI, BOP, and PI as response parameters for each analysis. The model included the two main effects of treatment and time, together with the two-way interaction of these factors. The control group was compared with each of the retainer groups in terms of periodontal parameters using the independent samples *t*-test corrected for multiple comparisons.

Results

Out of the 184 recruited patients that had been orthodontically treated, 15 were excluded during the 2 year study period due to failure to attend at least one follow-up appointment (three in the GFR500 group, five in the GFR1000 group, and seven in the multistranded retainer group).

Intra-examiner repeatability was excellent for the MGI and PI as the Cohen's weighted kappa score was 0.76 ($P < 0.001$) and 0.80 ($P < 0.001$), respectively.

Success rate

Figure 3 shows the Kaplan–Meier survival curves for the tested maxillary and mandibular retainers. Overall,

significantly more failures in the upper as well as in the lower arch were seen in the GFR groups in comparison with the multistranded retainer group: GFR retainers were successful in approximately half of the cases [49 per cent (92/186)], whereas 88 per cent (161/182) of the multistranded retainers were still intact at the end of the 2 year study period ($P < 0.001$). There was no significant difference between the GFR500 and the GFR1000 groups ($P \geq 0.682$). In addition, there were no centre-related differences in success for any of the tested retainers ($P \geq 0.628$). Figure 4 shows the number of failures in each retainer group, subdivided into maxillary and mandibular groups, and gives an overview of the distribution between broken and detached retainers. The most frequent type of failure in the GFR groups was a broken retainer in the upper jaw [77 per cent of all failures (37/48)], whereas loosening was more common in the lower jaw [74 per cent of all failures (34/46)]. The most frequent type of failure in the multistranded group was retainer detachment in the upper as well as in the lower jaw [77 per cent (10/13) and 100 per cent (8/8), respectively of all failures]. The proportion of broken–detached retainers was significantly different between the GFR groups and the multistranded retainer group ($P \leq 0.015$). No significant difference in the proportion of broken–detached retainers was found between the GFR500 and GFR1000 ($P = 0.222$) groups.

Modified gingival index

The periodontal implications of the different retainers at the different time points are shown in Table 2. Over the entire

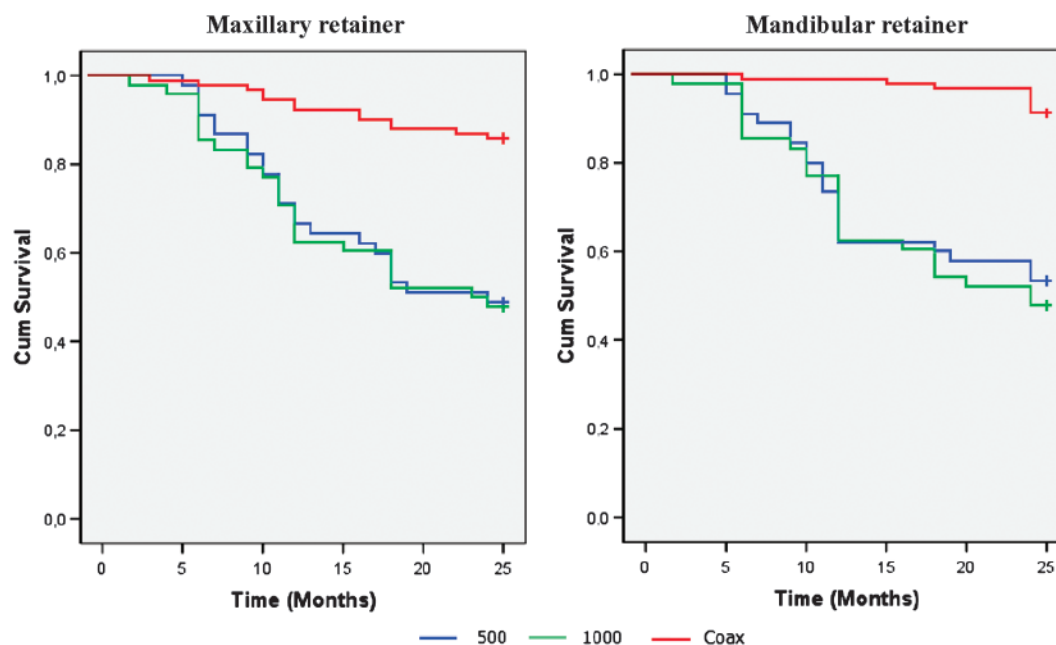


Figure 3 Survival curves of the maxillary (left) and mandibular (right) glass fibre reinforced GFR bonded orthodontic retainers containing 500 unidirectional fibres (blue), GFR1000 (green), and multistranded bonded orthodontic retainers (red).

study period, the MGI significantly increased in all groups to a maximum, on average, of more than 1.5 for the GFR retainer groups and nearly 1 for the multistranded retainer group ($P \leq 0.028$). At each assessment, the MGI was significantly higher for the GFR groups in comparison with the multistranded retainer group ($P < 0.001$). There were no significant differences between the GFR500 and the GFR1000 groups at any time point. With a mean MGI level of 0.22, the subjects in the control group showed significantly less gingival inflammation in comparison with patients wearing lingual retainers ($P < 0.001$).

Bleeding on probing

Gingival bleeding tendency showed a very similar course as the MGI (Table 2). BOP significantly increased in all groups over time ($P \leq 0.013$). Bleeding intensity was systematically higher in the GFR retainer groups in comparison with the multistranded retainer group ($P \leq 0.038$), yet, no significant difference between the GFR500

and GFR1000 groups was observed. Patients with a lingual retainer showed significantly higher bleeding scores in comparison with subjects in the control group ($P < 0.001$).

Plaque index

Plaque levels remained virtually unchanged in all groups over the entire study period (Table 2). In addition, there were no significant differences among the retainer groups at any time point. Subjects in the control group showed significantly lower plaque levels in comparison with patients wearing lingual retainers ($P \leq 0.001$).

Discussion

This appears to be the first large-scale long-term clinical study on the success rate and periodontal implications of GFR bonded orthodontic retainers. The aim was to evaluate the reliability and periodontal implications of this type of retainer in comparison with a gold standard (multistranded bonded orthodontic retainer) and negative control (subjects without retainers).

The results demonstrated significantly lower success rates for GFR retainers compared with multistranded retainers (49 versus 88 per cent). Similar findings have been described for polyethylene ribbon-reinforced retainers when compared with multistranded retainers (Rose *et al.*, 2002). Several explanations could account for the present observations: (1) GFR composite retainers have a low flexibility, which is related to the fact that interdental areas are usually splinted by composite, inducing high strain levels on the latter under loading (Årtun, 1984). When strain levels exceed the cohesive or adhesive strength of the material, microcracks form and eventually cause loosening

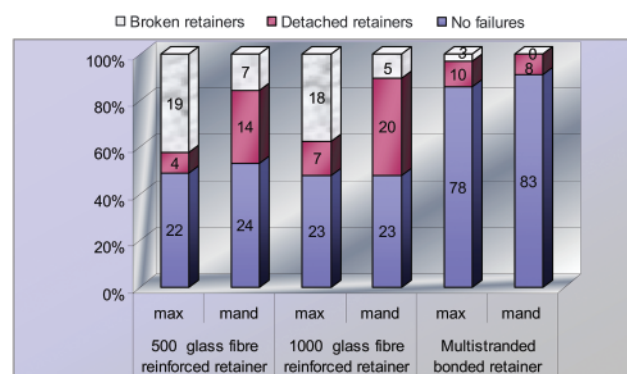


Figure 4 Distribution of the failure type, after 24 months.

Table 2 Periodontal implications of the tested retainers at different time points measured using the modified gingival (MGI), bleeding on probing (BOP), and the plaque (PI) indices; Glass fibre reinforced bonded orthodontic retainers containing 500 unidirectional fibres (GFR500), 1000 unidirectional fibres (GFR1000), multistranded bonded orthodontic retainers (MR), and the control group (control).

Parameter	Group	6 months	12 months	18 months	24 months
MGI	GFR500	1.20 (0.43)	1.00 (0.30)*	1.28 (0.36)*	1.51 (0.45)*
	GFR1000	1.09 (0.46)	1.09 (0.34)	1.20 (0.33)	1.55 (0.37)*
	MR	0.71 (0.29)**	0.61 (0.29)**	0.70 (0.27)**	0.98 (0.54)*,***
	Control				0.22 (0.17)***
BOP	GFR500	0.72 (0.22)	0.89 (0.19)*	0.82 (0.23)	1.00 (0.35)*
	GFR1000	0.76 (0.18)	0.81 (0.21)	0.89 (0.23)	1.06 (0.29)*
	MR	0.46 (0.18)**	0.55 (0.19)**	0.57 (0.21)**	0.84 (0.38)*,***
	Control				0.22 (0.09)***
PI	GFR500	1.88 (0.74)	2.32 (0.93)*	2.25 (0.78)	2.11 (0.73)
	GFR1000	2.03 (0.84)	2.12 (0.77)	2.48 (0.69)	2.18 (0.79)
	MR	1.74 (0.92)	2.09 (0.82)	2.07 (0.76)	2.14 (0.78)
	Control				1.32 (0.88)***

*Significant within group difference in comparison to previous reassessment.

**Significant difference between MR and GFR500 and MR and GFR1000.

***Significant difference between control and GFR500, control and GFR1000, and control and MR.

or fracture. Retainers are generally placed immediately following orthodontic therapy and at that time tooth mobility is usually high (Tanaka *et al.*, 2005), possibly further increasing strain. (2) The most appropriate glass fibre location to reinforce a composite retainer is at the tension side, which is buccally for well-aligned anterior teeth (Chung *et al.*, 1998; Ellakwa *et al.*, 2001; Dyer *et al.*, 2004). Evidently, for reasons of aesthetics, this could not be done. (3) Placing GFR composite retainers is a complex and technique-sensitive procedure. Shortcomings such as the isolation method, omitting the use of a rubber dam, may have led to suboptimal results. A rubber dam was not used in the present study, as this would not reflect daily practice in orthodontic offices. On the other hand, placement procedures had been strictly standardized. This is confirmed by the fact that there were no significant differences in the success rate for any of the tested retainers among the centres.

Retainer loosening was the most prevalent failure except for GFR retainers in the maxilla. For 77 per cent of these failures, the retainers broke, which can be explained by acute occlusal contact of antagonistic teeth in the area of the retainer's composite (Radlanski and Zain, 2004).

Well-balanced groups at baseline are essential for a high quality parallel study. Therefore, baseline recordings are imperative. In this study, periodontal parameters were not recorded prior to the start of the study, as these would have been influenced by the former impact of the orthodontic appliances (Årtun *et al.*, 1997). However, homogenous groups can be assumed because: (1) The patients were sequentially assigned to the different retainer groups. (2) The large sample size most probably ruled out significant differences in low/high plaque formers and oral hygiene disparities among the groups. (3) All participants completed a questionnaire on home care prior to the start of the research revealing no significant differences in this respect.

The results of this study indicate that the presence of a bonded orthodontic retainer, irrespective of its type, induced periodontal complications. Indeed, subjects in the control group without retainers showed significantly lower levels of gingival inflammation and plaque accumulation when compared with patients in any retainer group, even though oral hygiene was reinforced and professional prophylaxis was undertaken at each assessment. After a period of 10 years, deepening of periodontal pockets and increase of calculus deposits and gingival recession may be expected in patients with bonded lingual retainers (Pandis *et al.*, 2007). Unexpected tooth movements have been reported following lingual retention (Katsaros *et al.*, 2007). Evidently, these findings indicate the need for correct patient selection when planning retention strategies. On the other hand, however, the detrimental results in terms of periodontal complications described in this report seem to be in contrast with short- (Årtun *et al.*, 1987, Heier *et al.*, 1997) and long- (Årtun 1984, Årtun *et al.*, 1997, Booth *et al.*, 2008) term studies which suggest acceptable compatibility of bonded lingual

retainers with periodontal health. In this regard, the lack of a control group is fundamental. Indeed, the periodontal status of patients provided with bonded lingual retainers was not compared with the status of subjects without retainers in those studies. In addition, it should be taken into account that the number of patients included in the present investigation was at least 3-fold in comparison with the studies referred to, thereby decreasing any weight of outliers.

Patients in the GFR retainer groups showed significantly more gingival inflammation than those in the multistranded retainer groups. The bulkiness of GFR retainers covering the embrasures, thereby promoting plaque retention, may explain this finding. However, no significant differences were found between the GFR and the multistranded retainer groups in terms of plaque levels. It may conceivably be that the PI (Quigley and Hein, 1962) was not sufficiently sensitive to discriminate subtle differences among these groups, especially in the interproximal areas. As a GFR retainer divides the lingual surface into two distinct parts, it becomes difficult to score plaque extension beyond the centre of the tooth surface. In contrast, single applications of composite attaches the multistranded retainer, making it possible to detect a continuous layer of plaque around the application and under the wire reaching the coronal third of the tooth surface. As a result, the plaque levels in the GFR retainer groups may have been underestimated. In future research, interval-scaled plaque indices (Matthijs *et al.*, 2001) or ordinal-scaled indices giving more weight to interproximal plaque accumulation (Elliott *et al.*, 1972) should be used. In addition, methods such as 'automatic image analysis' (Cosyn *et al.*, 2005) could be considered when quantifying plaque along retainers.

Finally, no significant differences were found between the GFR500 and GFR1000 groups for any parameter. Clearly, altering the amount of glass fibres had no impact on the success rate or periodontal implications.

Conclusions

Multistranded lingual retainers should remain the gold standard for orthodontic retention, although periodontal complications are common. GFR retainers showed unacceptably high failure rates and caused detrimental periodontal complications. Therefore, their use in clinical practice should be discouraged.

Address for correspondence

Professor Bart Vande Vannet
Department of Orthodontics
Dental Medicine
Free University of Brussels (VUB)
Laarbeeklaan 103
B-1090 Brussels
Belgium
E-mail: bart.vande.vannet@vub.ac.be

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