# EXPERIMENTAL FLEXURE CREEP EVALUATION FOR GFRP COMPOSITE ORTHODONTIC ARCHWIRES

**Carlos Alberto Cimini Junior, cimini@fem.unicamp.br**
Department of Mechanical Design, State University of Campinas, UNICAMP, Brazil

**José Daniel Diniz Melo, daniel.melo@ufrnet.br**
**Antonio Marcos de Medeiros, antoniomecanica@hotmail.com**
Department of Material Engineering, Federal University of Rio Grande do Norte, UFRN

**Estevam Barbosa de Las Casas, estevam@dees.ufmg.br**
Department of Structural Engineering, Federal University of Minas Gerais, UFMG, Brazil

**Edson Antonio Ferreira, edson.ferreira@uvv.br**
Vila Velha University Center, UVV, Brazil

***Abstract.*** *Tooth movement for correcting functional occlusion, main purpose of the Orthodontics, is clinically obtained through the application of light, but continuous forces imposed by an orthodontic system composed by archwires and brackets, which are attached to the teeth. The load-release system should behave elastically over the period of the treatment, ranging from weeks to months. Generally, orthodontic systems are made of metals such as stainless steel, Chrome-Cobalt alloy or Titanium alloys. However, the increasing concern from patients receiving orthodontic treatment with their esthetic appearance opened the opportunity for the use of new materials as an alternative to metals in wire and bracket manufacture. Glass Fiber Reinforced Plastic (GFRP) then appears as an excellent candidate due to the transparency of both the glass fibers and the polymeric resin. Different from metals, fiber reinforced composites can be primarily designed as a material and tailored for specific applications. Therefore, the use of GFRP in Orthodontics is only beginning and, with further developments, it is expected to present a consistent alternative as the material of choice for orthodontists. In this work, the flexure creep performance of a commercially available GFRP composite archwire was evaluated. Eight-hour three-point bending tests were conducted in a DMA (Dynamic Mechanical Analyzer) for temperatures 30ºC, 45ºC and 60ºC in order to evaluate the creep behavior of the wire compliance. Results demonstrated the time-dependency showing creep compliance decays of 8.18%, 8.46% and 12.8% respectively for temperatures of 30ºC, 45ºC and 60ºC. This information can be used to support clinical decisions for archwire selection.*

***Keywords****: orthodontic archwire, glass fiber, epoxy resin, flexure creep*

## 1. INTRODUCTION

Tooth movement for correcting functional occlusion, main purpose of the Orthodontics, is clinically obtained through the application of light, but continuous forces imposed by an orthodontic system composed by archwires and brackets, which are attached to the teeth. The load-release system should behave elastically over the period of the treatment, ranging from weeks to months.

A growing interest on mechanical properties comparison for orthodontic wires has been introduced since the 80s, due to the introduction of new wire options. Stainless steel, the traditionally material of choice in the clinical practice since the 40s, was increasingly substituted by nickel and titanium alloys inhe 70s, and by titanium-molybdenum alloys a decade later (Gurgel, Ramos e Kerr, 2001; Gravina et al., 2004).

Currently, composite materials archwires are commercially available as an important option for the orthodontists. The orthodontic treatment has become more common in adult patients, and the demand for improvement in the esthetic quality has been increasing (Imai et al., 1999). These materials associate superior properties of stiffness and strength, compatible to the metallic alloys, with the esthetic appearance, which is an important concern of the patient. Glass fiber reinforced plastics (GFRP) are particularly suitable for this application, due to its relatively high specific stiffness and strength and almost transparent appearance (Watari et al., 1998). Esthetic differences between metal and GFRP orthodontic archwires can be observed in Figure 1.

Different from metals, fiber reinforced composites can be primarily designed as a material and tailored for specific applications. Therefore, the use of GFRP in Orthodontics is only beginning and, with further developments, it is expected to present a consistent alternative as the material of choice for orthodontists.

However, due to the intrinsic time-dependant properties of the polymeric matrix, GFRP may present a viscoelastic behavior (Zufall and Kusy, 2000). The relaxation of the orthodontic force could then be suitable for the treatment. On the other hand, three-point bending tests are considered standards for orthodontic wire mechanical behavior assessment (ISO15841, 2006). Therefore, in this work, the flexure creep performance of a commercially available GFRP composite archwire was experimentally evaluated.

(a) (b)

Figure 1 - Esthetics of metal (a) and GFRP (b) orthodontic archwires (Clear Wire, 2010)

## 2. MATERIALS AND METHODS

Flexure creep compliance was evaluated using three-point bending for specimens of GFRP (Glass Fiber Reinforced Plastic). In this study, a commercial available GFRP orthodontic archwire OPTIS™ (TP Orthodontics) Superior Straight Arch with 0.018” (0.46 mm) diameter was selected to obtain the test specimens. The specimens with 32 mm length were cut from the linear portions at the back of the orthodontic archwire (Figure 1). Therefore, each archwire provided two straight specimens.

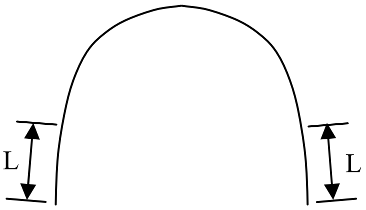

Figure 2 – OPTIS™ Superior Straight Arch and regions where specimens were cut

Flexure creep compliance was evaluated using simple three-point bending creep tests (Figure 3) on a Dynamic Mechanical Analyzer (DMA) Model Q800 (TA Instruments). The test setup is shown in Figure 4.

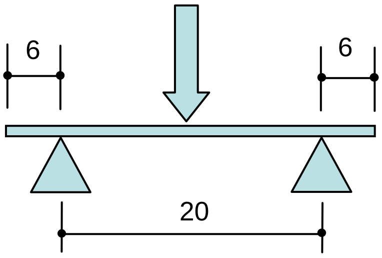

Figure 3 – Three-point bending creep test schematic view (dimensions in mm)

Figure 4 - Test setup for three-point bending creep test

The DMA mechanically deforms the specimen and measures its response. The deformation was applied in a constant (step) fashion and the response was monitored as a function time, keeping the temperature constant.

Mechanical properties involved in the linear theory of viscoelasticity can be obtained from stress relaxation and creep tests. The constitutive relations are:

$$\varepsilon[c\sigma(t)] = c\varepsilon[\sigma(t)] \tag{1}$$

$$\varepsilon[\sigma_1(t-t_1)+\sigma_2(t-t_2)] = \varepsilon[\sigma_1(t-t_1)]+\varepsilon[\sigma_2(t-t_2)] \tag{2}$$

Equation (1) represents the proportionality relation, i.e., a stress cσ(t) will produce a strain equivalent to that produced by the stress σ(t) multiplied by the constant c.

Equation (2) represents the linear superposition principle, i.e., if a stress σ1 is applied at a time t1 and an additional stress $\sigma_2$ is applied at a later time $t_2$, than the strain output at some time t ($t > t_2$) will be equal to the summation of the strain outputs from each stress acting independently.

First it was necessary to verify if the material presented linear viscoelastic behavior, i.e., if it complies with the requirements of proportionality and linear superposition principle (Eqs. (1) and (2)). Creep strains for one minute were determined under applied three-point bending stresses of 10 MPa, 20 MPa and 25 MPa. If the assumption of proportionality holds, the strain must also increase in the same proportion of the applied stress increase. One-minute tests were conducted at room temperature, and the linear viscoelastic behavior was checked.

After linear viscoelastic behavior was verified, 8-hour three-point bending creep tests were performed at constant temperatures of 30°C, 45°C and 60°C and constant stress level of 25 MPa.

## 3. RESULTS AND DISCUSSION

Results of one-minute three-point bending tests for verifying linear viscoelastic behavior of the material are presented in Figure 5. This figure shows a verification of proportionality. It can be observed that the material presented linear viscoelastic behavior, since the creep strain for the three different stress levels applied (10, 20 and 25 MPa) present linear relation, according to Eq. (1) (Figure 6).

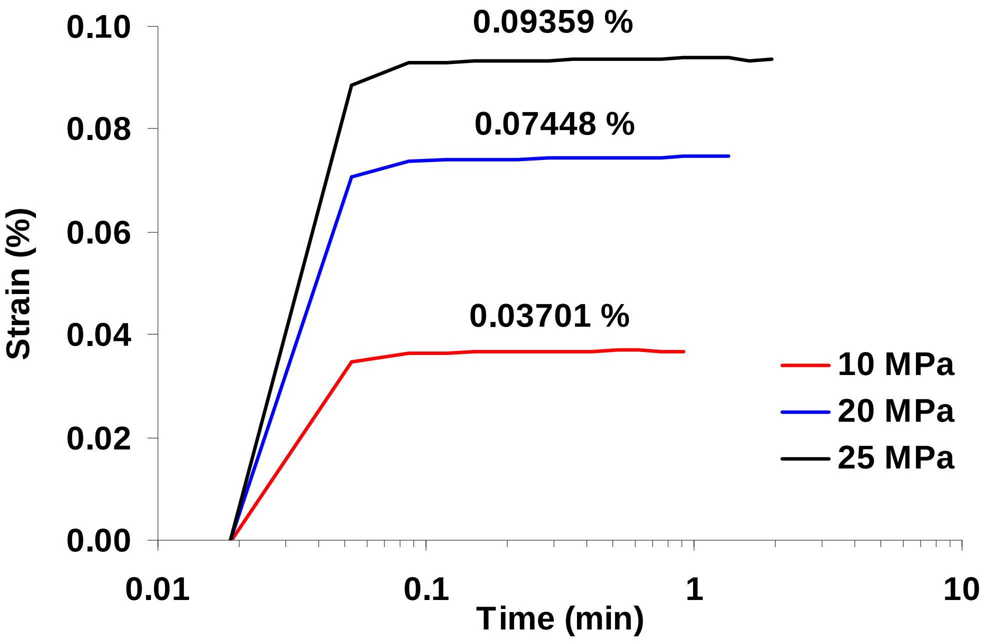

Figure 5 – Test results for linear stress-dependency for flexure creep behavior of GFRP orthodontic archwire up to 25 MPa and one minute

Results of eight-hour three-point bending tests for creep compliance behavior of the material are presented in Figure 7. The stress level used was 25 MPa. It can be observed a creep compliance increase, from 1 minute to and 475 minutes, of 3.31%, 3.69% and 7.50%, respectively for temperatures of 30ºC, 45ºC and 60ºC.

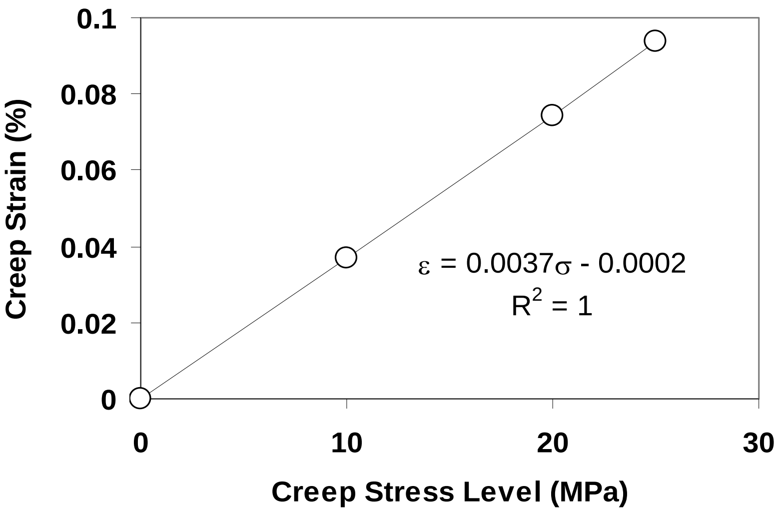

Figure 6 – Linear stress-dependency for flexure creep behavior of GFRP orthodontic archwire verified up to 25 MPa and 1 minute

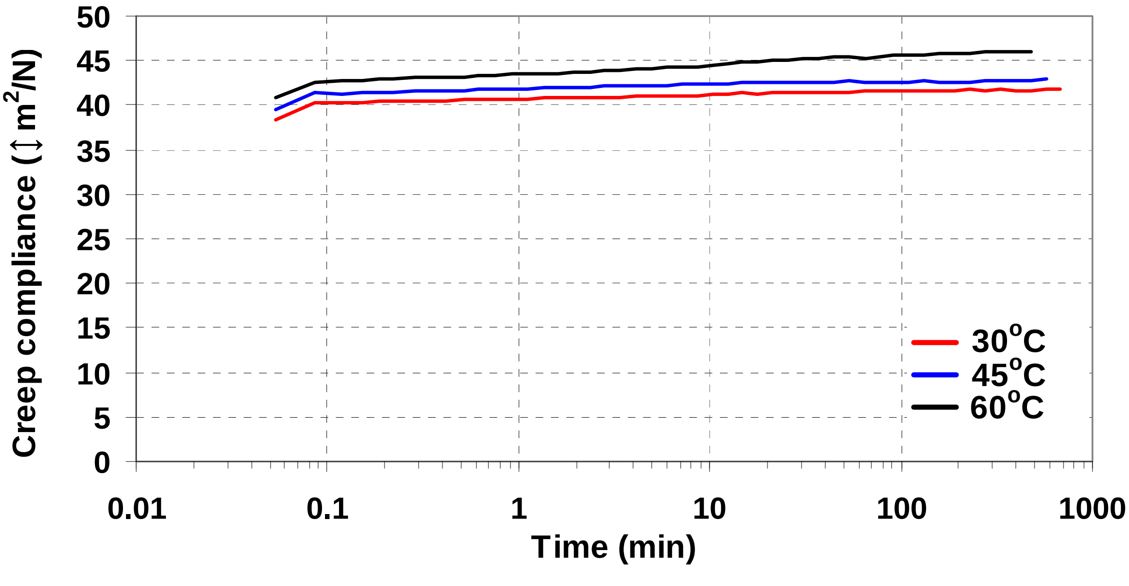

Figure 7 – Flexure creep behavior of GFRP orthodontic archwire for $\sigma = 25$ MPa

## 3. CONCLUSIONS

The clinical use of GFRP orthodontic archwires should take into account creep compliance increase. Test results showed compliance increase of up to 7.50% at 60ºC and 475 minutes (7.9 hours). With this information in mind, orthodontists can better support their clinical decisions for archwire selection.

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## REFERENCES

Gravina, M.A., Motta, A.T.S., Almeida, M.A.O., Quintão, C.C.A. Fios ortodônticos: propriedades mecânicas relevantes e aplicação clínica. Revista Dental Press de Ortodontia e Ortopedia Facial, 9(1):113-128, 2004.

Gurgel, J.A., Ramos, A.L., Kerr, S.D. Fios ortodônticos. Revista Dental Press de Ortodontia e Ortopedia Facial, 6(4):103-114, 2001.

Imai T, Yamagata S, Watari F, Kobayashi M, Nagayama K, Toyoizumi H, Uga M, Nakamura S, Temperature-dependence of the Mechanical Properties of FRP Orthodontic Wire, Dental Materials Journal, 18 (2): 167-175, 1999

ISO 15841 - Dentistry wires for use in orthodontics, International Organization for Standardization, 2006.

Watari F, Yamagata S, Imai T, Nakamura S, The fabrication and properties of aesthetic FRP wires for use in orthodontics, Journal of Materials Science, 33:5661-5664, 1998.

Zufall SW, Kusy RP, Stress relaxation and recovery behaviour of composite orthodontic archwires in bending, European Journal of Orthodontics, 22:1-12, 2000.

Clear Wire, The Translucent Wire for Orthodontics from BioMers Products, accessed in September 01, 2010, http://www.clear-wires.com/what-is-clear-wire.php#

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