EFFECT OF FLUORIDE SOLUTIONS ON THE STRUCTURE AND HARDNESS OF PLASTIC BRACKETS

Aim: To investigate the surface morphology, structure, molecular and elemental composition, and hardness of plastic brackets exposed to fluoride solutions. Methods: Two types of plastic brackets (Silkon Plus and SpiritMB) were exposed to three fluoride solutions 10 times for 1 minute each and then subjected to attenuated total reflectance-Fourier transform infrared (ATR-FTIR) spectroscopy, scanning electron microscopy (SEM), x-ray energy dispersive microanalysis (EDS), and Vickers hardness (HV) testing. Hardness data were analyzed via two-way ANOVA and Tukey tests at the .05 level of significance with brackets and fluoride solution as predictors. Results: ATR-FTIR spectroscopy showed that both bracket types consisted of polycarbonate. After treatment with acidulated phosphate fluoride, an increased contribution of –OH peaks at 3,200 cm⁻¹ (stretching [str]) and 1,640 cm⁻¹ (a type of vibration [b]) was observed in both brackets. SEM revealed that the acidulated phosphate fluoride solution had a strong effect on the morphology and surface structure of the two brackets; a general deterioration with projections of the reinforcing fibers was observed. EDS showed evidence of aluminum, calcium, silicon, magnesium, and titanium, which could be attributed to the reinforcing glass fiber constituents. Hardness ranged in the order of 20 HV with no difference among the two bracket types and the three fluoride exposures. Conclusion: Repeated exposure of plastic brackets to fluoride solutions has a pronounced effect on their structure and morphology, but not their hardness. World J Orthod 2010;11:398–403.

Key words: plastic brackets, hardness, morphology, fluoride exposure, SEM

The demand for esthetic orthodontic appliances stimulated interest in ceramic and plastic brackets. The superior esthetics and inert character of ceramic brackets have made them an integral part of clinical practice. In spite of their hardness, their tie wings fracture easily, which often makes these brackets inoperable. Alternatives include plastic brackets, consisting mostly of fiber-reinforced polycarbonate, which possess a higher ductility than ceramic brackets. However, the hardness and stiffness of the former is reduced and they are negatively affected by various factors present in the oral cavity.

The first plastic brackets, made of unfilled polycarbonate molding powder, were introduced in the 1970s. Reinforced polycarbonate brackets gained popularity in the 1990s when enamel damage caused by ceramic brackets during debonding became evident.

The esthetic advantage of plastic brackets, coupled with their low modulus of elasticity that facilitates peel-off debonding, made them particularly appealing. However, the plastic brackets currently available present too low a wear resistance. In addition, their structural integrity is compromised by various substances with which they come in contact.
Their torque transfer to the teeth is impaired because of their plastic deformation, as well.\textsuperscript{5,6} Therefore, the development of clear brackets synthesized of high-crystalline polymers with increased hardness and stiffness, decreased water sorption, and improved resistance to degradation is desirable.\textsuperscript{6} The resistance of such brackets to fluctuating and low pH in the presence of alcoholic beverages is unknown and may compromise their integrity and function, as polymers are prone to plasticization and softening. No evidence is available regarding the effect fluoride has on plastic attachments.

Fluoride solutions are used in orthodontics to protect against demineralization.\textsuperscript{7} The effect of fluorides on metal has been investigated, revealing a deleterious effect on the integrity of the surface oxide layer of titanium alloys, which may facilitate corrosion.\textsuperscript{8}

This study was initiated because no data are available on the effect of fluoride on plastic brackets, especially in regard to morphology, structure, and hardness. Specifically, the plasticization of the material with the subsequent softening was to be evaluated.

### METHOD AND MATERIALS

The plastic brackets investigated were: Silkon Plus (American Orthodontics) and SpiritMB (ORMCO). Sixteen specimens of each brand were divided into four groups. The first group served as a control, whereas the three others were exposed to acidulated phosphate fluoride (APF), sodium fluoride (NaF), or stannous fluoride (SnF\textsubscript{2}).

All brackets were embedded in epoxy resin, ground with water-cooled silicon carbide (SiC) paper (220 to 2,000 grit), and polished up to 0.05 alumina suspension (Buehler) in a grinding/polishing machine (Ecomet 3, Buehler). Each bracket type was subjected to 10 immersion cycles lasting 1 minute each. All specimens were then subjected to the following:

- Microattenuated total reflectance Fourier transform infrared (micro-ATR-FTIR) spectroscopy to characterize the changes in the molecular composition of the bracket surfaces induced by the three fluorides. Spectra acquisitions were performed on an FTIR spectrometer (Spectrum GX) equipped with a micro-ATR accessory (Golden Gate MKII, Specac) operating under the following conditions: 4,000 to 400 cm\textsuperscript{-1} range, 4 cm\textsuperscript{-1} resolution, 50 scans coaddition, diamond minicrystal, 45-degree edge and single internal reflection, and 2.0 mm depth of analysis at 1,000 cm\textsuperscript{-1}.

- Scanning electron microscopy (SEM) to investigate the morphologic changes induced by the three fluorides. Backscattered electron images were taken of the surface of specimens employing an SEM (Quanta 200, FEI) operated under 1 torr pressure, 30 kV accelerating voltage and 110 μA beam current.

- X-ray energy dispersive microanalysis (EDS) to assess the elemental composition of the brackets following exposure to the three fluoride solutions. A liquid nitrogen–cooled EDS detector (Sapphire, EDAX) with a super ultrathin beryllium (Be) window was used under LV operation. Two EDS spectra were collected from each specimen under 0.4 and 0.8 torr to subtract the LV background effect. The spectra were acquired under 25 KV accelerating voltage, 110 μm beam current utilizing at 600 μm sampling window, 150-second acquisition time, and 33% dead time. The qualitative and quantitative analysis was performed by Genesis 5.2 software (EDAX) under a nonstandard mode, employing ZAF correction methods.

- Vickers hardness (HV) testing with a microhardness tester (HMV-2000, Shimadzu) for 15 seconds under a 20 g load. Three measurements were obtained from each bracket specimen.

Hardness data were analyzed with two-way ANOVA and the Tukey test at the .05 level of significance, with bracket type and fluoride solution as predictors.
RESULTS

Figures 1a and 1b show the FTIR spectra of the two brackets subjected to the three fluoride solutions. The brackets seem to share identical composition, and show increased hydroxyl (–OH) peaks at 3,200 cm⁻¹ (stretching [str]) and 1,640 cm⁻¹ (a type of vibration [b]), following immersion in APF. No significant effects were observed for the other two fluoride solutions.

Figures 2a and 2b depict the SEM surface of the two bracket types following immersion in APF. Their surfaces show porosities, irregularities, and multiple projecting fibers relative to the controls (not shown).
Figures 3a and 3b depict the EDS spectra of as-received Silkon Plus and SpiritMB brackets, respectively. The high carbon content is attributed to their organic matrix; (c) a fiber of the SpiritMB bracket showing its high inorganic content consisting mainly of silicon, calcium, aluminium, magnesium, and titanium; and (d) the SilkonPlus and (e) SpiritMB brackets following exposure to APF revealing residual fluorine peaks, which imply adsorption of fluoride.
Table 1 shows the two-way ANOVA for hardness. None of the three solutions seem to have a significant effect on the hardness of both brackets. Table 2 demonstrates the Tukey grouping of the bracket-solution combinations, which were mostly in the order of 20 HV, with no difference among the groups.

**DISCUSSION**

Despite the frequent application of plastic brackets, no evidence exists on the reactivity of polycarbonates with the various substances they are exposed to intraorally. Fluoride was chosen as the factor to be examined because it is applied routinely through toothbrushing and as a preventive measure against caries. Another reason was that fluoride has demonstrated a deleterious effect on other orthodontic materials, particularly titanium alloys.8–11

The results of the present study show that the hardness of the plastic was not affected by the three fluoride solutions. It should be noted, though, that the in vitro environment of this study does not reflect the intraoral conditions. Thus, a direct extrapolation of these results to clinical practice should not be attempted. It could also be that throughout the entire treatment, the number of fluoride cycles imposed on a bracket exceeds the value utilized in this investigation.

Polymeric brackets show distinctive differences to metallic ones. The latter exhibit cyclic hardening or softening depending on their composition, previous cold work, and temperature. In contrast, polymeric materials display a cyclic softening effect.12,13 Polymer is also affected by loading and ambient temperature changes, which lead to a reduced fatigue life.

Hardness was studied because it is a key property for the performance of a bracket. The fact that most plastic brack-
ets are manufactured from low modulus raw material limits their performance.\textsuperscript{14,15} Vickers hardness is generally minimal in plastic brackets, generally about 20 HV. Most wires exceed this value by a factor of 20 to 30, especially nickel-titanium wires.\textsuperscript{15} Thus, it can be projected that wires will impose severe deformation of the slot walls when sliding over the slot surfaces, which impedes movement. Similarly, application and maintenance of torque is impaired with plastic brackets because of their permanent deformation.\textsuperscript{16}

The results of the SEM analysis revealed an increased irregularity of the bracket surfaces. The formation of micro- and projections precludes a complete wire engagement. This may jeopardize bracket effectiveness because the prescribed preadjustments will not be transferred.

The increased –OH peaks observed in the APF group may be attributed to the low pH value of that solution relative to the others. Its acidity may also be responsible for its aggression on the surfaces of plastic brackets. Polymers with higher crystallinity present increased hardness and resistance to wear.\textsuperscript{13} Brackets fabricated from polyoxymethylene consistently demonstrate a lower roughness and a higher hardness relative to their polycarbonate counterparts.\textsuperscript{8} However, polyoxymethylene brackets lack adequate transparency and good color stability.

**CONCLUSION**

The surfaces of plastic brackets exposed to APF show an increase in irregularities and complexity along with adsorption of fluoride. Both facts may have a clinical implication. However, exposure to the fluoride solutions tested does not influence the hardness of the both plastic bracket types investigated.

**REFERENCES**