Evaluation of frictional resistance and surface characteristics after immersion of orthodontic brackets and wire in different chemical solutions: A comparative in vitro study

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ABSTRACT

Aim: To evaluate the changes of static and kinetic frictional forces between the brackets and wires following exposure to a soft drink, acidic food ingredient, and acidulated fluoride prophylactic agents.

Materials and Methods: Two types of Roth prescription mandibular incisor brackets were used: 3M Unitek Victory stainless steel (SS) brackets (n = 40) and Transcend 6000 polycrystalline alumina (PCA) brackets (n = 40) as well as eighty 0.019 × 0.025” dimension ortho technology SS wires of 50 mm length each. Subsequently, brackets tied with SS wires divided into eight subgroups (n = 10) and were immersed in vinegar (pH = 3.5 ± 0.5), Pepsi® (pH = 2.46), Colgate Phos-Flur mouth rinse (pH = 5.1), and artificial saliva (control group pH = 7) for 24 h. Changes in surface morphology under scanning electron microscope ×1000, surface roughness (Ra) with surface profilometer (single bracket and single wire from each subgroup), and frictional resistance using universal testing machine were evaluated.

Results: Highest mean (standard deviation) static frictional force of 2.65 (0.25) N was recorded in Pepsi® followed by 2.57 (0.25) N, 2.40 (0.22) N, and 2.36 (0.17) N for Vinegar, Colgate Phos-Flur mouth rinse, and artificial saliva groups, respectively. In a similar order, lesser mean kinetic frictional forces obtained. PCA brackets revealed more surface deterioration and higher frictional force values than SS brackets. A significant positive correlation was observed between frictional forces and bracket slot roughness (r = 0.861 and 0.802, respectively, for static and kinetic frictional forces, p < 0.001 for both) and wire roughness (r = 0.243 and 0.242, respectively, for static and kinetic frictional forces, p < 0.05 for both).

Conclusions: Findings may have long-term implications when acidic food substances are used during fixed orthodontic treatment. Further, in vivo studies are required to analyze the clinical effect of acidic mediums in the oral environment during orthodontic treatment.

Keywords: Corrosion, fluoride mouthwash, friction, orthodontic brackets and wires, Pepsi®, surface roughness, vinegar

With the straight wire technique, bracket-wire friction affects the sliding movements of the teeth during space closure or canine retraction. Corrosion defects on the surface of the orthodontic appliance will influence both static and kinetic friction. Static friction is the force needed to start movement, whereas kinetic friction is the force needed to maintain movement once started. In the presence of friction during orthodontics, tooth movement apparently occurs as a sequence of very short steps or jumps rather than as a smooth, continuous motion.

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The variations of temperature and pH caused by diet, decomposition of foods, cell debris, oral microflora, and their byproducts are also important factors to be considered when evaluating the clinical behavior of orthodontic components that remain in the oral cavity for months or years. Changes in mechanical characteristics of orthodontic brackets and wires immersed in acidic electrolytes could be related to different factors such as the concentration of fluoride ions present in the solution, pH of the solution, manufacturing characteristics, and the duration of immersion. Various acidic food items such as tamarind pulp, lime juice, vinegar, pickles, and carbonated soft drinks are regularly consumed by populace.

Variations in pH due to dietary products or the conversion of sugars into acid by dental biofilm, determine the limit of salivary capacity to protect teeth, with pH 5.5 being the critical level, which could be sufficient to cause corrosion

Intraoral pH can fluctuate between 2.2 and 8.5, depending on the food we eat and drink. The strong acidity of citrus fruits, juices, pickles, and carbonated soft drinks may lower the salivary pH to 2 or lower, and the alkaline pH of soups, salty nuts, and fluoride mouthwashes is likely to increase the pH to 8.5 or higher. Such fluctuations can corrode orthodontic devices.

There were controversies in various studies regarding the effects of the acidity rate on the performance and characteristics of orthodontic alloys. Kwon et al. reported that through increasing the acidity (reducing pH), increased elements released from the alloy causing corrosion, which increased friction between titanium-containing wires and steel brackets, while according to Harris et al., the acidity of the environment did not have any effect on the properties of the alloy.

Limited information is available on the effects of acidic food ingredient Vinegar, carbonated soft drink Pepsi, and mouthwash Colgate Phos-Flur mouthwashes influencing the surface morphology and frictional characteristics between bracket-wire interfaces. It, therefore, becomes imperative to test out the surface changes on the brackets and archwires when exposed to such acidic mediums. As documented information and evidence for clarification is scarce in this perspective, this study was conducted to evaluate surface morphological changes and surface roughness on brackets and archwires and their frictional parameters when exposed to certain acidic solutions in the form of commonly consumed continental foods and a fluoride prophylactic agent.

AIMS AND OBJECTIVES

Aim
The prime aim of this study was to determine whether exposure of orthodontic stainless steel (SS) brackets, polycrystalline alumina (PCA) brackets, and SS archwires to acidic soft drinks, certain acidic food ingredients, and acidulated fluoride prophylactic agents affect the frictional properties between brackets and archwires by causing surface irregularities.

Objectives
- To evaluate and compare surface morphological changes and surface roughness of SS brackets, polycrystalline alumina brackets, and SS archwire after 24 h immersion in Pepsi, Vinegar, and acidic mouthwash Colgate Phos-Flur with neutral artificial saliva used as control
- To evaluate and compare the static and kinetic frictional resistance of SS, polycrystalline alumina brackets against a SS archwire after 24 h immersion in Pepsi, Vinegar, and acidic mouthwash Colgate Phos-Flur with neutral artificial saliva used as control.

MATERIALS AND METHODS

In this study, two types of 0.022-in slot Roth prescription mandibular incisor brackets of 0° tip and 0° torque value were tested: SS brackets (Victory Series, 3M Unitek, Monrovia, California, USA) and PCA brackets (Transcend 6000 Series, 3M Unitek, Monrovia, California, USA). A total of 80 brackets, which included 40 of each type were used. The 0.019 × 0.025” dimension SS archwire was used for testing (Ortho Technology, Tampa, Florida). Each wire specimen was of 50 mm length, cut from straight lengths. A total of 80 wire segments were used. The clear super-slick modules were used (TP Orthodontics, La Porte, Indiana, USA) to ligate bracket to wire in frictional analysis.

The test solutions were:
- Artificial saliva (control solution), pH of 7 containing methylcellulose 0.5% w/v and glycerin 30% w/v per 5 ml of solution (ICPA health products Ltd., 286 GIDC, Ankleshwar)
- Vinegar, pH of 3.5 ± 0.5 containing 4% w/v acetic acid (Sailor “Boy”, H.M.Z. condiments Pvt. Ltd., Chennai, India)
- Pepsi, pH of 2.46 containing 534 ppm of phosphoric acid (Pepsico India Holdings Pvt. Ltd., Dist. Raigad, India)
- Colgate Phos-Flur mouth rinse, pH of 5.1 containing 1.23% sodium fluoride acidulated phosphate; 0.04% w/v sodium fluoride (Vita Biopharma Pvt. Ltd., Daman, India).

There were eighty brackets and eighty wire segments in total (n = 80). They were divided into two major groups as Group A and Group B [Figure 1]. Group A consisted of forty SS brackets and forty SS wire segments (n = 40). Group B consisted of forty PCA brackets and forty SS wire segments (n = 40). Each major group was further divided into four subgroups of ten brackets and ten wire samples per subgroup. That means Group A was divided into four...
subgroups: I, II, III, and IV and Group B was divided into four subgroups: V, VI, VII, and VIII. Subgroups I and V were considered as control groups soaked in artificial saliva only. All other subgroups were considered as the experimental groups: II and VI soaked in Vinegar, III and VII in Pepsi®, and IV and VIII in Colgate Phos-Flur. Both control and experimental groups were immersed in their respective solutions for 24 h before testing, after which they were removed, washed in running water, and air-dried.

Testing surface morphology
To evaluate the surface morphology single bracket and single wire from each subgroup was randomly selected and their surfaces were studied under scanning electron microscope (SEM) (JSM-6380A, JEOL, Mumbai, India,) with 10–20 kV and ×1000. SEM images were taken.

Testing surface roughness
Surface roughness of all the test specimens were evaluated and using surface profilometer (SV, Mitutoyo, Tokyo, Japan) with a diamond stylus of 5 µm radius, which moved across the surface of prescribed length under a constant load (3.5 mN) and computes the numeric values representing the roughness average of the profile as “Ra,” the arithmetic mean of absolute values of the surface departures from the mean plane height. Two millimeters of bracket slot and 4 mm of archwire segment length were evaluated.

To recorded Ra value, experimental mounting template models were prepared using a 4 × 2 × 1” prefabricated commercial clear acrylic plates and used for mounting for the brackets. A horizontal line was drawn in the middle of the plate parallel to its long axis with black multimark pen (Faber-Castell) and at 10 mm from one end of the plate a vertical line perpendicular to horizontal line was scribed and at the point of intersection of these two lines, a bracket of the test sample was stabilized using industrial adhesive (Fevikwik) with the slot parallel to the vertical line to act as a guide for reproducible bond position. Subgroup numbering from Group I to VIII was made with a red marking pen (Faber-Castell) on the other end of the mounting plate and Ra values recorded.

Testing friction
Friction was measured with a universal testing machine (model 3382, Instron, Wycombe, and Buckinghamshire, United Kingdom) at a room temperature of 25°C in the dry state; SS wire segment was held in mounted bracket slot with module at 25 mm from the lower end of the archwire, to form a test unit. Then, the whole bracket-wire assembly with the mounting template was then positioned vertically in the lower jaws of the floor-mounted Instron universal testing machine. The free upper end of the archwire was gripped by the upper jaws of Instron universal testing machine, which was connected to the load cell [Figure 2].

The 10 N load cell was calibrated between 0 and 10 N, the machine was adjusted in the tensile mode and the archwires were drawn through the brackets as the

Figure 1: Consort diagram to represent group
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The force required to initiate (Static Force) and maintain movement (Kinetic Force) of the bracket at the 5th mm test distance was measured by the computer in Newton in a digital graphical read out. The universal testing machine measured the tensile force required to pull the wire through fixed bracket, along with tracking distance as a digital read out in lengths of millimeter as the cross head traveled superiorly up the wire. Peak values in the graphs represented static and kinetic friction. Similarly, friction was measured and recorded for all the eighty test units. Each bracket was tested only once and each wire specimen was drawn through one bracket only, to eliminate the influence of wear. Thus, for one subgroup, ten tests were carried out and the average was recorded. All the tests were done at room temperature in dry conditions.

Statistical analysis
Recorded Ra values, static and kinetic frictional force values of all bracket-arch wire combinations were analyzed using statistical package SPSS software (version 17, SPSS, Chicago, IL, USA). Descriptive statistics including means and standard deviations (SDs) are summarized in Tables 1 and 2. One-way analysis of variance (ANOVA) followed by multiple comparison of means procedure the post hoc test, Turkey test, and paired t-test were calculated to compare and evaluate significant differences in surface roughness, static and kinetic friction between and among 2 types of brackets and SS wire [Tables 3–5]. Pearson correlation coefficient test was applied to correlate Ra values with static and kinetic friction values [Table 6]. The level of significance for all tests was set at $P < 0.05$.

RESULTS

Scanning electron microscope analysis
Findings revealed all the test brackets and wire surfaces showed different degrees of pitting, surface irregularities, and roughness in all the testing solutions [Figures 3–5]. Pepsi immersed brackets showed greater amount of surface breakdown, especially on PCA brackets.

Surface profilometer analysis
Data revealed [Table 1] the highest mean arithmetic roughness value $Ra = 0.33 \mu m$ for Pepsi® immersed PCA brackets and the lowest mean $Ra = 0.047 \mu m$ for artificial saliva (control) immersed SS brackets.

Among Group A (SS) brackets, the higher mean slot roughness $Ra = 0.07 \mu m$ was found with subgroup III (Pepsi® + SS bracket) followed by $Ra = 0.062 \mu m$ for subgroup II (vinegar + SS bracket), $Ra = 0.055 \mu m$ for subgroup IV (Phos-Flur + SS bracket), and $Ra = 0.047 \mu m$ with subgroup I (artificial saliva + SS bracket).

Among Group B (PCA) brackets, the highest mean slot roughness $Ra = 0.33 \mu m$ was found with subgroup VII (Pepsi® + PCA bracket) brackets followed by $Ra = 0.27 \mu m$ with subgroup VI (vinegar + PCA bracket), $Ra = 0.20 \mu m$ with subgroup VIII (Phos-Flur + PCA bracket), and $Ra = 0.17 \mu m$ with subgroup V (artificial saliva + PCA bracket).

One-way ANOVA results revealed [Table 3] statistically significant difference in slot roughness at $F = 475$, $p < 0.001$ level was found between SS and PCA brackets in all the four test solutions. SS wires showed lesser morphological changes and mean surface roughness than SS brackets in all four test solutions and there was no correlation in the roughness between brackets and wires.

Table 1: Mean surface roughness (Ra) values (µm)

| Samples (n) | Artificial saliva | Vinegar | Pepsi® | Phos-Flur |
|-------------|-------------------|--------|--------|-----------|
| SS wire     | 80                | 0.017  | 0.026  | 0.041     | 0.015     |
| SS brackets | 40                | 0.047  | 0.062  | 0.07      | 0.054     |
| PCA brackets| 40                | 0.17   | 0.27   | 0.33      | 0.2       |

SS=Stainless steel, PCA=Polycrystalline alumina, Ra=Mean roughness

Table 2: Descriptive statistics of static and kinetic friction

| Samples (n) | Static Force | Kinetic Force |
|-------------|--------------|---------------|
| SS wire     | 80           | 12.5          |
| SS brackets | 40           | 0.8           |
| PCA brackets| 40           | 0.5           |

Statistical analysis

Recorded Ra values, static and kinetic frictional force values of all bracket-arch wire combinations were analyzed using statistical package SPSS software (version 17, SPSS, Chicago, IL, USA). Descriptive statistics including means and standard deviations (SDs) are summarized in Tables 1 and 2. One-way analysis of variance (ANOVA) followed by multiple comparison of means procedure the post hoc test, Turkey test, and paired t-test were calculated to compare and evaluate significant differences in surface roughness, static and kinetic friction between and among 2 types of brackets and SS wire [Tables 3–5]. Pearson correlation coefficient test was applied to correlate Ra values with static and kinetic friction values [Table 6]. The level of significance for all tests was set at $P < 0.05$.

RESULTS

Scanning electron microscope analysis
Findings revealed all the test brackets and wire surfaces showed different degrees of pitting, surface irregularities,
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Findings revealed [Table 2] for all bracket-wire test units, static force was higher than the kinetic force in all the four test solutions. The highest mean static and kinetic forces were measured in subgroup VII (Pepsi® immersed PCA bracket-wire test units), whereas they were least in subgroup IV (artificial saliva immersed SS bracket-wire test units). One-way ANOVA results [Tables 5 and 6] showed statistically significant difference at $F = 39.5$ and 24.9, respectively, for static and kinetic frictional forces ($P < 0.001$) found between SS and PCA bracket-wire test units in all test solutions for both frictional forces.

Static and kinetic frictional force values among Group A (stainless steel brackets)

The higher mean (SD) static and kinetic frictional force of 1.79 (0.11) N and 1.49 (0.18) N, respectively, were found for subgroup III (Pepsi® + SS bracket-wire test units) followed by subgroup II (v Vinegar + SS bracket-wire test units) 1.71 (0.25) N and 1.45 (0.16) N and subgroup IV (Phos-Flur + SS bracket-wire test units) 1.60 (0.13) N and 1.40 (0.19) N. Subgroup I (artificial saliva + SS bracket-wire test units) showed the least 1.54 (0.37) N and 1.35 (0.43) N, respectively.

Static and kinetic frictional force values among Group B (polycrystalline alumina brackets)

For static and kinetic frictional force values among Group B, the higher mean (SD) found with subgroup VII (Pepsi®

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**Table 2: Mean frictional force values in test solutions**

| Group                      | Subgroup | Samples (n) | Test solutions | Frictional force (N) | Static mean | SD  | Kinetic mean | SD  |
|----------------------------|----------|-------------|----------------|----------------------|-------------|-----|--------------|-----|
| Group A (SS bracket + SS wire) | I        | 10          | Artificial saliva | 7                    | 1.54        | 0.37 | 1.35         | 0.43 |
|                            | II       | 10          | Vinegar         | 3.5±0.5              | 1.71        | 0.25 | 1.45         | 0.16 |
|                            | III      | 10          | Pepsi®         | 2.46                 | 1.79        | 0.12 | 1.49         | 0.18 |
|                            | IV       | 10          | Phos-Flur       | 5.1                  | 1.60        | 0.13 | 1.40         | 0.19 |
| Group B (PCA bracket + SS wire) | V        | 10          | Artificial saliva | 7                    | 2.36        | 0.17 | 2.16         | 0.43 |
|                            | VI       | 10          | Vinegar         | 3.5±0.5              | 2.57        | 0.25 | 2.25         | 0.35 |
|                            | VII      | 10          | Pepsi®         | 2.46                 | 2.65        | 0.25 | 2.31         | 0.09 |
|                            | VIII     | 10          | Phos-Flur       | 5.1                  | 2.40        | 0.22 | 2.22         | 0.15 |

SS=Stainless steel, PCA=Polycrystalline alumina, SD=Standard deviation

**Table 3: One-way analysis of variance for surface roughness of Group A and Group B brackets**

|              | Sum of squares | df | Mean square | $F$  | Significant |
|--------------|----------------|----|-------------|------|-------------|
| Between groups | 0.837          | 7  | 0.120       | 475.041 | 0.000*** (S) |
| Within groups  | 0.018          | 72 | 0.000       |      |             |
| Total         | 0.855          | 79 |             |      |             |

***P<0.001, S=Significant

**Table 4: One-way analysis of variance for comparing static frictional force**

|              | Sum of squares | df | Mean square | $F$  | Significant |
|--------------|----------------|----|-------------|------|-------------|
| Between groups | 15.015          | 7  | 2.145       | 39.537 | 0.000*** (S) |
| Within groups  | 3.906           | 72 | 0.054       |      |             |
| Total         | 18.921          | 79 |             |      |             |

***P<0.001, S=Significant

**Table 5: One-way analysis of variance for comparing kinetic frictional force**

|              | Sum of squares | df | Mean square | $F$  | Significant |
|--------------|----------------|----|-------------|------|-------------|
| Between groups | 13.435          | 7  | 1.919       | 24.927 | 0.000*** (S) |
| Within groups  | 5.544           | 72 | 0.077       |      |             |
| Total         | 18.979          | 79 |             |      |             |

***P<0.001, S=Significant

**Table 6: Pearson correlation coefficient between frictional force and surface roughness**

|              | Static frictional force | Kinetic frictional force |
|--------------|-------------------------|--------------------------|
| Surface roughness of SS and PCA brackets | 0.861** | 0.802** |
| Pearson correlation | $<0.001$ | $<0.001$ |
| $n$ | 80 | 80 |
| Surface roughness of SS wire | 0.243* | 0.242* |
| Pearson correlation | 0.030 | 0.031 |
| $n$ | 80 | 80 |

**Correlation is significant at the 0.01 level (two-tailed). *Correlation is significant at the 0.05 level (two-tailed). SS=Stainless steel, PCA=Polycrystalline alumina**

**Figure 3:** Scanning electron microscope microphotographs of stainless steel bracket slot surface ($\times$1000) (a) Control group stainless steel bracket (b) Vinegar group stainless steel bracket (c) Pepsi group stainless steel bracket (d) Phos-flur group stainless steel bracket
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Figure 4: Scanning electron microscope microphotographs of stainless steel bracket slot surface (x1000) (a) Control group polycrystalline alumina bracket (b) Vinegar group polycrystalline alumina bracket (c) Pepsi group polycrystalline alumina bracket (d) Phos-flur group polycrystalline alumina bracket

Figure 5: Scanning electron microscope microphotographs of stainless steel wire surface (x1000) (a) Control group stainless steel wire (b) Vinegar group stainless steel wire (c) Pepsi group stainless steel wire (d) Phos-flur group stainless steel wire

+ PCA bracket-wire test units) to be 2.65 (0.24) N and 2.31 (0.09) N, followed by subgroup VI (vinegar + PCA bracket-wire test units) to be 2.57 (0.25) N and 2.25 (0.34) N and subgroup VIII (Phos-Flur + PCA bracket-wire test units) to be 2.42 (0.21) N and 2.22 (0.14) N. Subgroup V (artificial saliva + PCA bracket-wire test units) showed the least 2.36 (0.17) N and 2.16 (0.19) N, respectively.

Relationship between the frictional force and surface roughness
Pearson correlation coefficient showed a significant positive correlation between frictional forces and bracket slot roughness ($r = 0.861$ and 0.802, respectively, for static and kinetic frictional forces, $p < 0.001$ for both), as well as wire roughness ($r = 0.243$ and 0.242, respectively, for static and kinetic frictional forces, $p < 0.05$ for both) [Table 6].

DISCUSSION
The outcome of orthodontic treatment to a large extent depends on how well the forces and the resultant reactions are controlled. Whenever sliding mechanics are used in orthodontics, friction is generated between brackets and archwire and that has a major impact on the force ultimately delivered to teeth.[13] In general, factors affecting frictional resistance between archwire and brackets, varies with archwire size and material,[14-17] mode of ligation, bracket width,[13,18] angulations of wire to bracket, and biological and environmental factors[18,19] such as saliva, bacterial plaque, acquired film, and corrosion.[17]

Orthodontic appliances present in the oral cavity when exposed to the aggressive action of Cl$^-$ or Fl$^-$ ions in saliva or from low pH[20] acidic food and drink undergo rapid dissolution of surface oxide layer of the metal because of thermodynamical instability and releases of iron, zinc, silver, nickel,[21] and chromium ions until equilibrium was reached or impedance occurs.[22] Results in surface dissolution of ceramic materials and pitting corrosion and surface roughness. Released cytotoxic elements[23] can produce discoloration of adjacent soft tissues and allergic reactions in susceptible patients.

In this study, depending on their acidity, experimental group orthodontic brackets and wires exhibited different corrosion behaviors and varying degrees of roughness in acidulated Phos-Flur mouthwash, Pepsi®, and vinegar. Similarly, static and kinetic frictional force values also increase with respect to surface roughness. Mean frictional force values of our control group brackets and wire combination correlated well with the studies of Kao et al.,[23] and Doshi and Bhad-Patil.[24] SS wires showed lesser surface roughness than brackets.

Even though surface roughness is an inherited characteristic of the material, its shelf time, surface imperfections due to corrosion, resistance to deterioration otherwise called creep/relaxation, and the manufacturing processes such as polishing and heat treatment, influence surface roughness.[13] Like few other studies,[24-30] the present study also demonstrated PCA brackets are significantly rougher and have higher coefficient of friction than SS brackets in all the acidic test solutions.

Among our test solutions, highly acidic Pepsi® with pH of 2.46 immersed brackets and wires showed more surface irregularities, pitting, breakdown, debris, roughness, and highest static and kinetic frictional forces followed by Vinegar group with pH of 3–4 and Phos-Flur group with pH of 5–6. This is because of acidic ingredients such as phosphoric acid, 4% acetic acid, and hydrofluoric acid[23] present, respectively, in Pepsi®, Vinegar, and Phos-Flur promote corrosion and breakdown. As acidity increases, the tendency toward breakdown and surface roughness of orthodontic appliances also increases.[5]

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Generally, friction tends to be highest for very rough or very smooth surfaces. This could be due to the effects of roughness. This depends not only on the degree of surface roughness but also on the geometry of roughness, orientation of roughness features, passive surface film, and relative hardness of the two contacting surfaces.[2]

Ceramic corrosion either by dissolution of the entire surface or by preferential dissolution of sintering agents, leading to a porous, rough surface layer with inferior mechanical properties.[17,27] Very rough surfaces can cause high friction because of the contact and interlocking of peaks and valleys[22,29-32] although the opposite has also been suggested.[33]

Instead, metallic materials are not susceptible to corrosion as long as the surface oxide film is intact, but when the breakdown potential of an alloy is reached, the oxide layer dissolves and surface corrosion and pitting commence.[1] Even though oxygen is necessary to form and maintain acidity and chloride ions can be particularly detrimental to surface protective film of an orthodontic alloy.[18,34,35]

Surface roughness of brackets and wires might affect esthetics and coefficient of friction.[1] In terms of complexity, 26.4% of orthodontic treatments were difficult or very difficult.[36] Whenever friction is generated between brackets and archwire, especially in sliding mechanics; it tends to lessen the force actually received by a tooth.[13] Frictional forces may reduce the orthodontic force by 50% or more.[18] Hence, greater force is required to move the teeth; loss of anchorage further complicates orthodontic treatment mechanics. This has clinical implications in critical posterior anchorage cases such as reduction of large overjet[35] and bimaxillary protrusion malocclusion. Our findings showed a significant positive relationship between frictional forces and bracket slot roughness or wire roughness. It appears that bracket slot roughness plays a more significant role, reflecting on the correlation values of higher than 0.6, which tend to be more clinically important.[36] Orthodontic patients should be cautious having acidic food, beverages, and fluoridated substances.

Limitations

Limitations of the study were that the study was conducted after a continuous 24 h exposure of brackets and archwire to acidic mediums, whereas fluctuations in pH levels are likely to be expected intraorally as influenced by saliva and other food substances. Since surface profilometer study was an invasive technique, an additional surface damage likely to occur with diamond stylus. Further, preexposure voids and irregularities present on the bracket and wire surfaces make it difficult to accurately measure and study the surface roughness. The frictional resistance of bracket-arch wire combinations was also measured under dry condition, unlike the constantly wet oral environment.

CONCLUSIONS

The present study demonstrated definite deterioration in physical and mechanical properties of orthodontic brackets and wires following exposure to acidic substances. As the acidity increases (pH decreases) from artificial saliva to Pepsi®, surface breakdown and frictional forces increases. Even though degree of deterioration depends on the inherent nature of the material, both SS metal and inert ceramic corrodes easily by the acids. Orthodontic brackets and wire exposed to carbonated drink Pepsi® had highest surface roughness and frictional resistance followed by Vinegar and Colgate Phos-Flur mouth rinse. This finding may have long-term implications when acidic food substances used during fixed orthodontic treatment.

This study stresses upon the importance of the prudent and restricted use of carbonated drinks, preservative food, and fluoride mouthwashes during fixed orthodontic treatment. Since salivary pH influences the acidity of oral cavity and frictional properties of orthodontic materials, it’s likely to produce a difference in the degree of deterioration than our continuous 24 h exposure study. Further, in vivo studies are required to analyze the clinical effect of acidic mediums in the oral environment during orthodontic treatment.

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Conflicts of interest
There are no conflicts of interest.

REFERENCES

1. Kao CT, Huang TH. Variations in surface characteristics and corrosion behaviour of metal brackets and wires in different electrolyte solutions. Eur J Orthod 2010;32:555-60.
2. Prososki RR, Bagby MD, Erickson LC. Static frictional force and surface roughness of nickel-titanium arch wires. Am J Orthod Dentofacial Orthop 1991;100:341-8.
3. Regis S Jr., Soares P, Camargo ES, Guariza Filho O, Tanaka O, Maruo H. Biodegradation of orthodontic metallic brackets and associated implications for friction. Am J Orthod Dentofacial Orthop 2011;140:501-9.
4. Huang HH. Surface characterization and corrosion resistance of nickel-titanium orthodontic archwires in artificial saliva of various degrees of acidity. J Biomed Mater Res A 2005;74:629-39.
5. Alavi S, Barooti S, Borzabadi-Farahani A. An in vitro assessment of the mechanical characteristics of nickel-titanium orthodontic wires in Fluoride solutions with different acidities. J Orthod Sci 2015;4:52-6.
6. Yip HH, Wong RW, Hägg U. Complications of orthodontic treatment: Are soft drinks a risk factor? World J Orthod 2009;10:33-40.
7. Dawes C. What is the critical pH and why does a tooth dissolve in acid? J Can Dent Assoc 2003;69:722-4.
8. Oh KT, Choo SU, Kim KM, Kim KN. A stainless steel bracket for orthodontic application. Eur J Orthod 2005;27:237-44.
9. Marques IS, Araújo AM, Gurgel JA, Normando D. Debris, roughness
and friction of stainless steel archwires following clinical use. Angle Orthod 2010;80:521-7.

10. Alavi S, Farahi A. Effect of fluoride on friction between bracket and wire. Dent Res J (Isfahan) 2011;8 Suppl 1:S57-42.

11. Kwon YH, Cheon YD, Seol HJ, Lee JH, Kim HL. Changes on NiTi orthodontic wired due to acidic fluoride solution. Dent Mater J 2004;23:557-65.

12. Harris EF, Newman SM, Nicholson JA. Nitinol arch wire in a simulated oral environment: Changes in mechanical properties. Am J Orthod Dentofacial Orthop 1988;93:508-13.

13. Frank CA, Nikolai RJ. A comparative study of frictional resistances between orthodontic bracket and arch wire. Am J Orthod Dentofacial Orthop 1980;78:593-609.

14. Vaughan JL, Duncanson MG Jr., Nanda RS, Currier GF. Relative kinetic frictional forces between sintered stainless steel brackets and orthodontic wires. Am J Orthod Dentofacial Orthop 1995;107:20-7.

15. Kapila S, Angolkar PV, Duncanson MG Jr., Nanda RS. Evaluation of friction between edgewise stainless steel brackets and orthodontic wires of four alloys. Am J Orthod Dentofacial Orthop 1990:98:11-26.

16. Kusy RP, Whitley JQ. Coefficients of friction for arch wires in stainless steel and polycrystalline alumina bracket slots. I. The dry state. Am J Orthod Dentofacial Orthop 1990;98:300-12.

17. Lima VN, Coimbra ME, Derech CD, Ruellas AC. The frictional forces on stainless steel and plastic brackets using four types of wire ligation. Dent Press J Orthod 2010;15:82-6.

18. Drescher D, Bourauel C, Schumacher HA. Frictional forces between bracket and arch wire. Am J Orthod Dentofacial Orthop 1989;96:397-404.

19. Tidy DC. Frictional forces in fixed appliances. Am J Orthod Dentofacial Orthop 1989;96:249-54.

20. Schiff N, Grosseggeat B, Lissac M, Dalard F. Influence of fluoride content and pH on the corrosion resistance of titanium and its alloys. Biomaterials 2002;23:1995-2002.

21. Amini F, Borzabadi Farahani A, Jafari A, Rabbani M. In vivo study of metal content of oral mucosa cells in patients with and without fixed orthodontic appliances. Orthod Craniofac Res 2008;1:151-6.

22. Kim H, Johnson JW. Corrosion of stainless steel, nickel-titanium, coated nickel-titanium, and titanium orthodontic wires. Angle Orthod 1999;69:39-44.

23. Kao CT, Ding SJ, He H, Chou MY, Huang TH. Cytotoxicity of orthodontic wire corroded in fluoride solution in vitro. Angle Orthod 2007;77:349-54.

24. Doshi UH, Bhad-Patil WA. Static frictional force and surface roughness of various bracket and wire combinations. Am J Orthod Dentofacial Orthop 2011;139:74-9.

25. Gupta A, Balasubramaniam MR, Krishnaraj R. An in-vitro evaluation of frictional forces between conventional and ceramic and metal-insert ceramic orthodontic brackets. SMR Univ J Dent Sci 2011;2:24-7.

26. Nishio C, da Motta AF, Elias CN, Mucha JN. In vitro evaluation of frictional forces between archwires and ceramic brackets. Am J Orthod Dentofacial Orthop 2004;125:56-64.

27. Rose CM, Zernik JH. Reduced resistance to sliding in ceramic brackets. J Clin Orthod 1996;30:78-84.

28. Omana HM, Moore RN, Bagby MD. Frictional properties of metal and ceramic brackets. J Clin Orthod 1992;26:425-32.

29. Angolkar PV, Kapila S, Duncanson MG Jr., Nanda RS. Evaluation of friction between ceramic brackets and orthodontic wires of four alloys. Am J Orthod Dentofacial Orthop 1990;98:499-506.

30. Pratten DH, Popli K, Germane N, Gunsolley JC. Frictional resistance of ceramic and stainless steel orthodontic brackets. Am J Orthod Dentofacial Orthop 1999;98:398-403.

31. Kusy RP, Whitley JQ, Mayhew MJ, Buckthal JE. Surface roughness of orthodontic archwires via laser spectroscopy. Angle Orthod 1989;58:33-45.

32. Kusy R. Commentary – Ceramic brackets. Angle Orthod 1991;4:285-92.

33. Eliades T, Bourauel C. Intraoral aging of orthodontic materials: The picture we miss and its clinical relevance. Am J Orthod Dentofacial Orthop 2005;127:403-12.

34. Saunders CR, Kusy RP. Surface topography and frictional characteristics of ceramic brackets. Am J Orthod Dentofacial Orthop 1994;106:76-87.

35. Al-Khatib S, Berradja A, Celis JP, Willems G. In vitro friction of stainless steel arch wire-bracket combinations in air and different aqueous solutions. Orthod Craniofac Res 2005;8:96-105.

36. Borzabadi-Farahani A, Borzabadi-Farahani A, Eslamipour F. The relationship between the ICON index and the dental and aesthetic components of the IOTN index. World J Orthod 2010;11:43-8.

37. Tselepis M, Brockhurst P, West VC. The dynamic frictional resistance between orthodontic brackets and arch wires. Am J Orthod Dentofacial Orthop 1994;106:131-8.