Stem Durability Testing of Interdental Brush

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The purpose of the present study was to determine the ability of interdental brush to withstand repeated use and to relate this property to clinically observed fractures of such brushes. The stem durability test was conducted according to ISO (International Standards Organization) standard by using a bending at 90° under a 500-g controlled load (ISO/TC106/SC7/WG3). Two sizes (ss, m) of each of the five commercially available interdental brushes (D, B, P, I, S) were used. The cycle number at the time of fracture was noted for all interdental brushes. The fractured surfaces of the stem wire following the stem durability test were also observed under a scanning electron microscope. The specimens, when ranked in decreasing order of the number of cycles at which fracture occurred, were D-m, D-ss, B-ss, B-m>P-m, P-ss, I-ss, I-m, S-m, S-ss (P<0.05). L-type interdental brushes (P-m, P-ss, I-ss, I-m, S-m, and S-ss) showed significantly decreased fracture resistance when compared with straight-type interdental brushes (D-m, D-ss, B-ss, B-m). In all cases, the fracture was found to be of ductile nature.

Key words: Interdental brush, Twisted wire, Stem durability

INTRODUCTION

In order to prevent dental caries — a major public health problem in the oral cavity, various studies on fluoride-releasing dental materials have been done1 -3). Although fluoride is known to be effective — in some extent — to prevent dental caries, daily oral hygiene procedures are by far a very effective measure that prevents this disease and periodontal diseases too. In fact, tooth brushing is the most popular procedure for this purpose. Of late, various studies have reported on the effect of tooth brushing on the surface characteristics of dental materials4 -6). However, little scientific knowledge is available on the properties of toothbrushes themselves. Amongst the toothbrushes, manual interdental brushes are frequently used for mechanical plaque removal — primarily from the interdental region. However, interdental brushes can undergo fracture without any visible signs of previous, permanent deformation. Multi-filament manual interdental brushes, in which the stem is the central support structure of the manual interdental brush head, is usually composed of twisted wire which secures the filaments. The stem is either secured in the handle or plays the role of the handle itself. Recently, the International Standards Organization (ISO) developed a new test to determine the stem durability of interdental brushes7). This stem durability test is conducted by using a bending at 90° under a controlled load of 500 g. The purpose of the present work was to determine the ability of interdental brushes to withstand repeated use and to relate this property to clinically observed fractures of such brushes. Analysis of all interdental brushes was made with regard to the number of cycles at which fracture occurred, and the fractured surface of the wire after stem durability test was then observed under a scanning electron microscope.

MATERIALS AND METHODS

Two sizes of each of the five commercially available interdental brushes were examined in this study (Fig. 1). A summary of the brushes — in terms of brand, size, code, type (i.e., design type, straight or L), joint resin of stem wire, and manufacturer — is given in Table 1. Ten unused interdental brushes of each type were tested. This stem durability test was conducted according to ISO (International Standards Organization) standard by using a bending at 90° under a controlled load of 500 g (Fig. 2). The rotational cycle covered the movement from vertical position (0°) to a point 45° from the vertical in one direction, then to a point 45° in the opposite direction and back to the vertical position again (0°). Each manual interdental brush was subjected to repeated rotational cycles of the stem until the stem broke. Rotational cycle rate was 30 cycles per minute. The number of rotational cycles at which fracture occurred was noted for all interdental brushes. The test was conducted by using dry brushes at 23
Fig. 1 Photographs of commercially available interdental toothbrushes.

Fig. 2 (A) Apparatus used for the experiment. Gripping unit to secure the brush handle holds the stem in a stationary position. A 500-g load is attached to the end of the interdental brush head. This apparatus moves the interdental brush through a rotational cycle. (B,C) Diagrams of apparatus during the test. The initial condition (B) and the condition at the point 45° left from the vertical position (C) are shown.

Table 1 Materials tested

<table>
<thead>
<tr>
<th>Brand</th>
<th>Size</th>
<th>Code</th>
<th>Type</th>
<th>Joint resin of stem wire</th>
<th>Manufacturer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dental Pro</td>
<td>ss, m</td>
<td>D</td>
<td>Straight</td>
<td>Polyethylene</td>
<td>Jacks Co. Ltd. (Osaka, Japan)</td>
</tr>
<tr>
<td>Between</td>
<td>ss, m</td>
<td>B</td>
<td>Straight</td>
<td>Polyethylene</td>
<td>Lion Co. Ltd. (Tokyo, Japan)</td>
</tr>
<tr>
<td>PC clinica</td>
<td>ss, m</td>
<td>P</td>
<td>L</td>
<td>Polystyrene</td>
<td>Lion Co. Ltd. (Tokyo, Japan)</td>
</tr>
<tr>
<td>Ito-yoji</td>
<td>ss, m</td>
<td>I</td>
<td>L</td>
<td>Polystyrene</td>
<td>Kobayashi Co. Ltd. (Osaka, Japan)</td>
</tr>
<tr>
<td>Shikan Burashi</td>
<td>ss, m</td>
<td>S</td>
<td>L</td>
<td>Polypropylene</td>
<td>Ebisu Co. Ltd. (Nara, Japan)</td>
</tr>
</tbody>
</table>

ss: super small size
m: medium size
±2°C and 50±5% relative humidity. Statistical testing was done using one-way ANOVA followed by Scheffe's test \(P<0.05\) to identify significant differences between variables in this study. As for the analysis of the fracture face of each interdental brush, it was done using scanning electron microscopy (SEM) to determine the fracture mode.

**RESULTS**

**Fracture resistance**

Fracture resistance is the ability of the interdental brush to withstand bending and loading stress. Individual results for cyclic fatigue are displayed in Fig. 3. The value of S-ss was the lowest, while that of D-m was the highest. Ten interdental brushes were compared for fracture resistance (in terms of the number of rotational cycles at fracture). The specimens, when ranked in decreasing order of the number of cycles at which fracture occurred, were D-m, D-ss, B-ss, B-m>P-m, P-ss, I-ss, I-m, S-m, S-ss \(P<0.01\). The values of Group A (D-m, D-ss, B-ss, B-m) showed no significant differences between any two of them, nor did those of Group B (P-ss, P-m, I-ss, I-m, S-ss, S-m). In this study, Group B brush stems fractured at a lower cycle number than those of Group A. Thus, Group A stems had significantly better fracture resistance than those of Group B. In the same vein, the stems of Group B brushes (L-type interdental brushes) had a significantly shorter life expectancy.

**Fracture mode**

Fig. 4 shows the appearance of typical fractured surfaces after the stem durability test. As revealed by SEM, dimples – which are a feature of ductile fracture – were observed as crater-like formations on the face of each wire in all cases. No differences were found for the interdental brushes with respect to the effect of size or brand of commercial samples on dynamic fracture.

**DISCUSSION**

Effective plaque control, particularly the removal of interproximal plaque, is essential for preventing periodontal diseases and reducing interproximal caries. Unfortunately, plain tooth brushing is relatively ineffective at removing interproximal plaque. When the interdental space is small and completely occupied by gingival papilla, flossing can be considered as the method of choice. For larger interdental spaces, especially where there is gingival recession and the root is exposed, dental floss is not recommended. Instead, the use of an interdental brush is more appropriate.

Many different interdental brushes are currently on the market. Interdental brushes have been evaluated for effectiveness in interproximal plaque removal\(^8\)\(^-\)\(^11\). However, limited information about these brushes themselves, such as their physical properties, is available for the brush user or the oral health care provider\(^12\),\(^13\). It would thus be helpful to both the clinician and user alike if more physical data were available. The results of *in vitro* studies should be compared with those of clinical trials to ascertain their accuracy and reliability in predicting the behavior of interdental brushes *in vivo*. Interdental brushes can undergo fracture without any visible signs of previous, permanent deformation. Cyclic fatigue plays an important part in this process, and there is a clear need to develop a clinically acceptable test protocol to assess, and to define the standards of, fracture resistance of interdental brushes.

This study investigated the cyclic fatigue life of the stem of ten kinds of interdental brush. The analysis – based on fracture resistance to a bending and loading stress in the interdental brush stem – presented here showed the importance of the mechanical characteristics of the stainless steel wire and the resin joint of stem wire reinforcing the interdental brush stem. As evidenced by SEM, failure of the stainless steel wires was solely of a ductile nature. The micrographs showed a macroscopically smooth fracture face with crater-microvoid formations visible at higher magnification (Fig. 4). The soft resin (polyethylene) joint of Group A brushes showed better properties under repeated-stress situations than the hard resin joint material (polystyrene or polypropylene) of Group B brushes. Based on the results of this study, the theoretical deduction was that L-type design and hard resin joint would reduce the life span of interdental brushes. Indeed, the stems of L-type, hard resin joint brushes were
D-ss (the upper part), D-m (the lower part)  B-ss (the upper part), B-m (the lower part)

P-ss (the upper part), P-m (the lower part)  I-ss (the upper part), I-m (the lower part)

S-ss (the upper part), S-m (the lower part)

Fig. 4 SEM views of representative fractured surface following the stem durability test; original magnification ×180–×400. Crater-microvoid formation is observed (×400).
undoubtedly weakened by cyclic fatigue. However, assigning cyclic fatigue of interdental brush stems as the major cause of failure will necessitate further analyses.

REFERENCES