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FV Teche
HFO Paranhos
MFJ Motta
O Zaniquelli
C Tirapelli

Differences in abrasion capacity of four soft toothbrushes

Authors' affiliations:
FV Teche, HFO Paranhos, MFJ Motta, O Zaniquelli, C Tirapelli, Department of Dental Materials and Prosthesis, School of Dentistry of Ribeirão Preto, University of São Paulo, Brazil

Correspondence to:
C. Tirapelli
Avenida do Café sn
Bairro Monte Alegre
Faculdade de Odontologia de Ribeirão Preto-USP
Cep 14040904
Ribeirão Preto
São Paulo
Brazil
Tel./Fax: +55 16 36024152
E-mail: catirapelli@forp.usp.br

Abstract: *Objectives:* This study evaluated the flexibility and abrasion capacity of the bristles of four soft toothbrush brands. *Methods:* Toothbrushes from groups: 1: Aquafresh Flex; 2: Oral-B Indicator; 3: Colgate Classic; 4: Johnson and Johnson Reach were used for the buckling deformation flexibility assay with of load (40 g) for a 5-s period and the measurement of the diameter of the bristles using a comparison gauge (precision: 1 μm), and for the abrasion assay in a brushing machine in 100-min cycles with a standard dentifrice in a 1:1 solution with distilled water and load of 200 g. The data were normalized due to the difference in the size of the toothbrush heads and analysed by the anova and the Tukey test to adjust for multiple comparisons ($\alpha = 0.05$). *Results:* A significant difference in the flexibility of the bristles (toothbrushes from groups 2, 3 and 4 were more flexible than 1) was observed. There was no correlation between the increase in the diameter of the bristles and the reduction in flexibility. The statistical analysis revealed loss of mass due to abrasion, varying according to the flexibility of the bristles, with group 1 causing lower wear than groups 2, 3 and 4. *Conclusions:* The results of this study showed that there are variations in bristle flexibility abrasion potential of soft-classified toothbrushes.

Key words: abrasion; oral health; oral hygiene; self-care; tooth brushing

Introduction

Brushing associated with dentifrices continues being the most used and efficient procedure (1) of self-care in the practice of oral hygiene in most countries (2). Presently, there is a great variety of toothbrushes with several indications; however, scientific proofs that one is superior to the other are scarce (3, 4), which makes the professional's guidance to the patient more difficult. Nevertheless, to consider brushing as an efficient hygiene habit, one must consider the elimination of the oral biofilm and the possibility of maintaining the hygiene habit without injuring the tissues that receive the action.

The use of toothbrushes and dentifrices in the oral hygiene practice can impact the abrasion of soft and hard tissues under the mechanical brushing action. Considering that brushing is usually connected to the use of dentifrices, and also depends on who operates the brush, it is important to asses which factors involved would be responsible for the abrasion and the consequences (5, 6). According to Dyer *et al.* (2000) (7), the abrasion capacity of hard tissues by soft bristle toothbrushes is equal or superior to hard-bristle toothbrushes when the addition of dentifrices

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is considered, as is the routine in oral hygiene. There is consensus that the hard-bristle toothbrushes should not be recommended due to their destructive potential on the soft and hard tissues.

It is worth pointing out the difficulties in the patients' motivation for oral hygiene, especially when they have to be educated regarding the change in their habits. Thus, the study of the toothbrush' characteristics can contribute to the improvement and adequate selection of the toothbrush. Therefore, the objective of this study was to assess the bristle diameter and flexibility using the buckling deflection test and the abrasion capacity of four soft toothbrush brands using an *in vitro* brushing assay.

Materials and methods

Eighty toothbrushes were used, 20 of each of the following commercial brands: 1: Aquafresh Flex; 2: Oral-B Indicator; 3: Colgate Classic; 4: Johnson and Johnson Reach. The dentifrice Colgate with calcium[4] was used as a cleaning aid together with the toothbrushes. Of the eighty toothbrushes, 40 were used as a bristle source for the evaluation of their diameter and the flexibility test. The remaining toothbrushes, together with the selected dentifrice, were employed in the abrasion assay by brushing. In the brushing test, commercially available transparent acrylic was used with substrate to make the test bodies:

1 Aquafresh, Smithkline Beecham, Rio de Janeiro, Rio de Janeiro, Brazil.
2 Oral-B, Gillette do Brazil, Manaus, Amazonas, Brazil.
3 Colgate-Palmolive, São Bernardo do Campo, São Paulo, Brazil.
4 Johnson and Johnson, São José dos Campos, São Paulo, Brazil.

Diameter evaluation

Bristle preparation: bristles were cut close to their anchorage point, approximately 10 mm long, preserving the architecture. The bristles were individually positioned for the measurement and later discarded. The measurement of the diameter was done in a profilometer (Nikon, Nippon Kogaku K.K., Japan) with a precision of tenths of millimetres (0.01 mm). Ten values for each commercial brand tested were obtained.

Flexibility test

The variations in the toothbrush bristle flexibilities were determined using the Buckling deflection test, which consists of the application of a force on the extremities of the previously selected bristles, in the direction of the long axis. The bristles used in the experiment were initially cut close to their anchorage point in the respective toothbrushes; with a length of 10 mm. Groups of five bristles were obtained from each tested brush, for a total of 10 groups of five bristles, of each commercial brand tested.

An optic microscope base was used in preparation of toothbrush bristles, adapted for the fitting of the comparison gauge (CSE, Frankfurt, Germany), capable of precisely measuring (0.001 mm) alterations in the lengths of the bristles upon minimal compression (40 g), conferred by the instrument stem.

The groups of bristles were positioned vertically, grouped by two matrixes, fixed, in the upper extremity, to the stem of the comparison gauge, and in the lower extremity, to the adapted microscope base. Both matrixes were developed with central perforations measuring 0.8 mm in width and 0.6 mm in depth, allowing for the free flexion of the bristles under compression. Each group was then positioned vertically, grouped with the aid of the matrixes, without initial compression due to the placement of a 10-mm-tall strut. After the positioning of the bristles, the strut was removed and the bristles received compression forces for 5 s for later measurement.

Brushing test

The brushing test was executed in machines especially created for this assay. The machine simulated the brushing of six samples simultaneously for 100 min (speed of 356 cycles per minute), in linear movements with an amplitude of 3.8 cm and a force of 200 g (8–10). The toothbrushes were cut 1 cm from the head and positioned in the machine. The test bodies, made of transparent acrylic, measured 90 mm in length, 30 mm in width and 3 mm in height. Sufficient volume of the dentifrice was suspended in distilled water (1:1 proportion) and poured in the apparatus trays over the already positioned test bodies.

The acrylic test bodies were maintained in an oven at 52°C for the previous 24-h period and after each assay, so as not to affect the weight of the bodies due to water gain. The Gravimetric method (weight measurement) was used to quantify the abrasion in a precision scale (sensitivity: 0.1 mg).

As the weight difference of the test bodies was obtained in an abrasion test with toothbrushes with different bristled areas, these data could not be compared without prior normalization. To normalize the data, indices based on the measurement of the bristled area length were created (perimeter) from each one of the four toothbrush models used with a flexible wire, without changing the position of the bristles.

The perimeters of heads of each toothbrush were obtained, and the smallest area was chosen as a reference, in other words, 100%. The reference values for the remaining areas (greater than 100%) were calculated and the exceeding value, expressed in percentages, was subtracted from the weight of the corresponding test bodies.

Results

The statistical normality and homogeneity tests were executed and the normal and homogenous distribution of the data was detected. Therefore, the statistical variance analysis tests and complementary Tukey test were performed, both at the 5% probability level.

Variation in the diameter of the bristles among the tested groups: the group 4 and group 2 toothbrushes showed statistically equal bristle diameters, but larger than those obtained in the group 1 and group 3 which were also equal (Fig. 1).

Data obtained in the buckling deformation assay were submitted to ANOVA (5%), which showed a difference in the flexibility of the toothbrush bristles between groups. The complementary Tukey test (5%) determined differences in the flexibility of the bristles: group 1 with less flexible bristles and group 4 and group 2 with more flexible bristles. Group 3 showed an intermediary performance on buckling deformation assay (Fig. 2).

The abrasion assay data by group were analysed by ANOVA (5%) and showed differences between the tested toothbrushes. The complementary Tukey test (5%) determined that the equal abrasion was promoted by the group 2, 4 and 3, which were statistically similar. The group 1 demonstrated the least abrasion (Fig. 3).

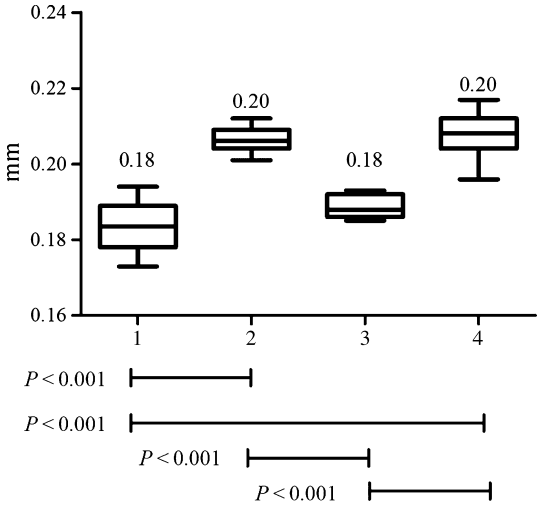

Fig. 1. Graphic illustration of diameter values from the assessments, presented separately for each group. The mean values are presented over each column. The statistical significance of the comparison between the groups is presented in the illustration.

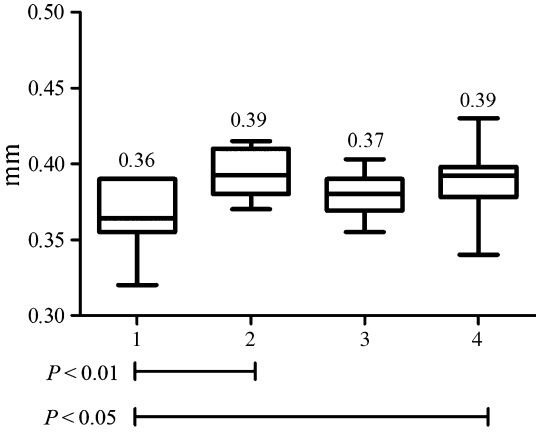

Fig. 2. Graphic illustration of buckling deflection from the assessments, presented separately for each group. The mean values are presented over each column. The statistical significance of the comparison between the groups is presented in the illustration.

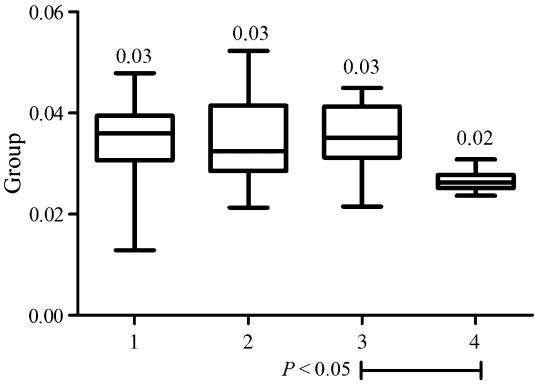

Fig. 3. Graphic illustration of abrasion from the assessments presented separately for each group. The mean values are presented over each column. The statistical significance of the comparison between the groups is presented in the illustration.

Discussion

Most studies involving toothbrushes are related to their dental biofilm-removal capacity. This study aimed at studying the toothbrushes regarding another aspect of their usage, surface abrasion. For this reason, the bristle flexibility and diameter were assessed, verifying the correlation of these factors with the capacity of abrasion. The toothbrushes were chosen based on commonly patient recommendation – use an of soft-bristle and flat bristle trimmed. The employment of the commercially available transparent acrylic (11) as a substrate in the abrasion test reduced possible alterations existing in test bodies made of resin, improving the reproducibility of the experiments.

The present study worked with the hypothesis that toothbrushes from the same category, in this case soft bristle, may not be the same regarding bristle flexibility and abrasion capacity. The initial hypothesis of this study differs from that of some authors who executed studies to check abrasion that there is no variation between categories, based on the manufacturer's flexibility ratings (3, 7, 12, 13), which, in turn, follow international norms (14, 15).

The flexibility test data show significant differences in bristle flexibility, considered to be from the soft category by the manufacturers. The flexibility of the bristles was determined by a new method, which assesses groups with a small number of bristles (five at a time) with the intent of more precisely assessing the filaments. As the bristles from the same category and material (nylon), according to the manufacturers, were tested under standardized conditions, it is expected that another factor is responsible for the variation. Among the possible factors, the diameter of the bristles remained as apparently being responsible for the variation factor. Therefore, the measurement of the bristles' diameter was done aiming at identifying if the differences in flexibility would be correlated

with the diameter. Contrary to what was expected, there was no correlation between the increase in the diameter and consequent reduction in the flexibility of the bristles, suggesting that the material used to produce the toothbrush bristles has differences, even if generally specified as nylon. These differences in the material of the bristles suggest that the toothbrush may be categorized in a more specific manner to each patient and that they need better descriptions from the manufacturers, as there is little difference in the information provided to professionals and patients in this area. The lack of specific information on the toothbrushes may not result in large differences in the lay patient's choice, as perception of stiffness can differ amongst different countries, but it certainly has a professional value, and its absence makes the adequate indication for each use more difficult.

The brushing abrasion test revealed differences in the abrasion capacity of toothbrushes, varying according to the flexibility of the bristles, a result that is in agreement with Dyer *et al.* (2000) (7). The explanation may be based on the fact that the toothbrush bristle characteristics make them more or less efficient as a vehicle for the dentifrice used in the brushing. Thus, the more flexible bristles caused more abrasion due to greater axial contact with the surface during the brushing, carrying a larger amount of abrasives against the same. On the other hand, the hypothesis of Phaneuf *et al.* (1962) (16), supported by Dyer *et al.* (2000) (7), also defends the increase in the abrasiveness because more flexible bristles have a smaller diameter, generating more numerous tufts and with a better dentifrice retention. This hypothesis was not confirmed in this study, as a correlation between the bristle diameter and the flexibility was not found. The bristles with a smaller diameter proved to be less flexible and caused less abrasion.

Although this variation in the flexibility of the bristles from the same category needs to be proven regarding its clinical importance, it has already proven to be significant enough to express different values in the *in vitro* abrasion test. The comparison between the data obtained in the bristle-flexibility tests revealed that the substrate abrasion values increased as the toothbrushes tested had bristles that are more flexible. Considering that significant differences between the toothbrushes in all tests executed were found, and that part of the literature is based on studies that presume that toothbrushes from the same classification are the same, there may be variations in the results obtained by many authors, even increasing the toothbrush's participation in its portion of surface abrasion. The results do not suggest the use of toothbrushes with harder bristles instead of the softer toothbrushes, as the behaviour of the soft and/or softened surfaces (gingival tissue and eroded enamel or dentin) regarding abrasion was not an integral part of this study, and the literature indicates that soft or softened tissues can be harmed by the use of inadequate tooth brushing techniques, toothpastes and toothbrushes (1, 17, 18).

Other aspects related to surface abrasion may influence the results obtained, and the number of factors is high. As an example of the factors, we can mention the strength employed on the brush, which is a modifying agent of the bristles' axial contact regardless of their flexibility and should be the aim of research as one of the moderating factors of the abrasion capacity of toothbrushes associated with the dentifrice, as well as the quality of the termination of the bristles, such as rounding and polishing. Regarding this point, a study performed with fifteen different manual toothbrushes examined the bristle end geometry. In that study, half of the products examined achieved a level of at least 90% acceptable bristle end rounding; five of the toothbrushes examined had between 70% and 90% acceptable bristle end geometries, while two products had less than 70% (19). It is important to mention that correlation between '*in vitro*' tests with clinical reality is difficult, especially because of the multifactorial nature of the *in vivo* tooth wear; (e.g. brushing technique, brushing force, time and frequency of brushing). The wear caused by '*in vivo*' brushing can vary largely; being more or less pronounced than '*in vitro*' wear (20, 21). Considering the limitations of this *in vitro* study, it is important to make a further comment about what we assume to be the main information obtained from these experiments: the toothbrush group classified as 'soft bristles' presents differences in the level of 'softness' which led to different levels of abrasion.

Further investigations should be performed to support our findings and recommend a possible change in toothbrushes classification.

Conclusions

Based on the results obtained, it has been concluded that:

1 There are significant differences in the flexibility of soft-bristle toothbrushes: Aquafresh Flex, Colgate Classic, Johnson and Johnson Reach, Oral-B Indicator.

2 There are significant differences in the diameter of soft-bristle toothbrushes: Aquafresh Flex, Colgate Classic, Johnson and Johnson Reach, Oral-B Indicator.

3 The toothbrushes with softer bristles promoted greater abrasion on the acrylic substrate in the brushing assay.

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