

A comparative Study of the Abrasive Effects of Different Toothpastes on Enamel

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Abstract

Objective: Tooth-brushing with toothpaste is the most common and also the most important method for maintaining oral hygiene. However, it may be associated with a side effect, namely tooth abrasion. Considering the wide variety of toothpastes available in the Iranian market and lack of comprehensive studies about their characteristics in our country, the present study was conducted to evaluate and compare two Iranian made whitening and anti-sensitivity toothpastes with two similar foreign-made products.

Methods: In this in-vitro experimental study, enamel samples were prepared and embedded in acrylic blocks. Initial surface profile of samples was measured by a profilometer. Samples were then subjected to a wear test in V8 cross brushing machine by the forward and backward strokes of toothbrushes in the machine in presence of a toothpaste solution. After washing and drying of samples, their secondary surface profile was measured by a profilometer. The difference between the obtained values before and after the abrasion was indicative of the abrasiveness of toothpastes in micron. Obtained data were entered SPSS software and analyzed using one-way ANOVA and Repeated Measures ANOVA.

Results: The abrasiveness of four understudy toothpastes was significantly different from one another ($P=0.039$). However, pair-wise comparison of toothpastes did not reveal a significant difference between Pooneh Whitening toothpaste and Crest 3D White or between Pooneh Anti-sensitivity toothpaste and Sensodyne ($P>0.05$). The only significant difference detected was between the two Iranian made toothpastes ($P=0.005$).

Conclusion: Based on the present study findings, no statistically significant difference exists between the abrasiveness of Iranian and foreign made toothpastes. However, similar studies are required in our country on the effects of toothpastes especially those simulating a clinical setting with the use of other measuring devices.

Key words: Toothpaste, Enamel, Abrasion, Profilometry

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Introduction:

Maintaining oral and dental health especially with the use of toothpaste is among the main subjects of training in preventive dentistry. Removal of dental plaque, elimination of exogenous stains and prevention of gingival and periodontal diseases as well as dental caries are among the benefits of tooth-brushing (1). Due to the positive chemical effects of toothpastes and delivery of several therapeutic agents, use of toothpastes is recommended (2, 3).

The cleansing effect of toothpastes depends on

their abrasive agent content (4). However, too much abrasivity can cause dentin abrasion, tooth hypersensitivity, esthetic problems and eventually damage to the masticatory system (5, 6). This condition is manifested more severely in cases with gingival recession and exposure of root surface into the oral cavity (7, 8).

Abrasivity, fluoride release rate, compatibility of the released fluoride with other toothpaste ingredients and cleaning ability are among the most important criteria for toothpastes and presence of optimal concentration of each ingredient in toothpaste makes it ideal (9).

The most important component of toothpaste is

its abrasive agent. The abrasiveness of toothpastes depends on the hardness, size and shape of abrasive particles. Abrasives are divided into 5 major categories of carbonates, phosphates, silica, aluminum and organic abrasives. The important point about them is that they have to be compatible with fluoride ion (10).

Apart from abrasive agents, polishing agents are also among the ingredients of toothpastes. Silica possesses both the abrasion and polishing properties (11).

Abrasion is a typical phenomenon in dentistry and is considered among the most important factors responsible for wear and destruction of tooth structure and dental restorative materials (12). The following methods are used for assessing the rate of abrasion:

1. Radioactive Dentin Abrasion (RDA)(13)
2. Profilometry
3. Stereomicroscopy
4. Reflex microscopy
5. Scanning Electron Microscopy (SEM)
6. Digital 3D computer graphics systems
7. Digital balance
8. Digital micrometer
9. Micrography (14)

It seems that the majority of primary abrasion studies, considering the less than optimal characteristics of primary resins introduced, have evaluated abrasion of restorative materials especially glass ionomers and resins. Momoi et al, in 1997 in an in-vitro study evaluated toothbrush-dentifrice abrasion of two resin-modified and two conventional glass ionomers, amalgam and a hybrid composite resin. The samples were subjected to toothbrush-dentifrice abrasion using 20,000 back and forth strokes of brushing. The amount of vertical surface loss was determined using profilometry and the surface abrasion was assessed by SEM analysis. The obtained results demonstrated that the abrasion resistance of resin-modified glass-ionomers was significantly lower than that of conventional glass ionomers.

Davis et al, in 1978 (16) in an in-vitro study evaluated the effect of tooth brushing (with and without toothpaste) on enamel and dentin abrasion after exposure to dietary acid. In their study, surface profilometry was used to evaluate the rate of abrasion. Their study results revealed

that tooth resistance to acid attacks is widely different from person to person.

Svinnseth et al, in 1987 (17) conducted a study on the abrasivity of 23 toothpastes available in the European market and evaluated its correlation with the pH of toothpastes. They used profilometry for this purpose. Dentin specimens were subjected to abrasion and then the abrasivity of each toothpaste was reported relative to a standard reference toothpaste. The obtained results revealed several significant differences between different toothpastes. Also, a significant correlation was found between the abrasivity and acidity of toothpastes.

Stookey et al, in 1982 (18) studied the effect of removal of stains and evaluated its correlation with toothpaste abrasiveness on enamel. This study was performed on 24 samples prepared from bovine teeth. Staining of samples was done within 4 days and then they were all subjected to wear/abrasion test. Results showed that by increased abrasiveness, stain removal by the toothpaste was enhanced.

In a study by Addy et al, in 1983 (19) dentine specimens were prepared from an impacted third molar tooth of subjects and were transferred into the oral cavity in a maxillary removable acrylic appliance. The appliance containing dentin specimen was removed and brushed ex vivo with the allocated paste for one minute five times a day. Using this method, it was demonstrated that the toothpaste with higher RDA value caused greater abrasion compared to the one with lower RDA value.

In 2007, Shahabi et al. evaluated the abrasive properties of three different toothpastes namely Daroogar, Pooneh and Colgate. This study was conducted on polymethacrylate blocks and the difference in weight of blocks before and after the abrasion was measured. They failed to find a statistically significant difference in the abrasivity of these three toothpastes.

MalekAfzali et al, in 1999 (21) evaluated the abrasiveness of three Iranian made children toothpastes and compared it with that of Oral-B toothpaste as a standard foreign reference paste. After completion of the abrasion phase of composite resin specimens in the V8 cross brushing machine, weight of specimens was compared with the baseline value before

abrasion. The results showed that Daroogar toothpaste especially in 15,000 strokes and higher caused a significantly higher abrasion compared to the other three toothpastes.

However, lack of such studies is evident in our country. Considering the massive production of toothpastes and the high demand for such products in our country, the need for these studies becomes more prominent. Since a limited number of studies have conducted on the abrasivity of Iranian toothpastes and their comparison with similar foreign ones, the present study was designed to compare the effects of two Iranian toothpastes with two standard foreign pastes on enamel abrasion. Although in the majority of published studies dentin abrasion has been evaluated, the fact is, in the absence of pathologic conditions, enamel is the first surface exposed to toothpaste and tooth brush. Thus, the authors of the present study evaluated the effect of toothpaste on enamel

abrasion.

Methods:

This in-vitro experimental study was conducted on sound extracted anterior teeth of patients aged 35-40 yrs. with normal systemic conditions presenting to private dental offices and clinics in Isfahan. The teeth had no caries, cracks, discolorations or enamel defects. The toothpastes used were Pooneh Whitening toothpaste (Goltash Co., Under license of Paksan Ltd, Isfahan, Iran), Crest 3D White (Procter and Gamble, Cincinnati, OH, USA), Pooneh Antisensitivity toothpaste (Goltash Co., Under license of Paksan Ltd, Isfahan, Iran) and Sensodyne Original (GlaxoSmithKline, Moon Township, PA, USA). Table 1 summarizes the characteristics of the abrasive ingredients of these toothpastes.

Table 1. Characteristics of the abrasive ingredients of toothpastes

Type of toothpaste	Type of abrasive agent	Size of particles	Shape of particles	Mass percent
Crest 3D Whitening	Dehydrated silica	8-12 micron	Spherical and symmetrical	25-40%
Sensodyne Original	Dehydrated silica	8-12 micron	Spherical and symmetrical	25-40%
Pooneh Anti-sensitivity	Dehydrated silica	8-12 micron	Spherical and symmetrical	25-40%
Pooneh Whitening	Dehydrated silica	8-12 micron	Spherical and symmetrical	25-40%

Using statistical methods, sample size was calculated as 24 samples that were divided into 4 groups of 6 samples each. For data analysis, the mean surface profile was calculated for each toothpaste before and after abrasion. The difference between the two mean values was indicative of the mean enamel abrasion in micron for that specific toothpaste.

Surface profile of samples was evaluated and measured using a profilometer (Taylor Hobson Ouo, Leicester, England) in the Biomaterial Laboratory of Isfahan University of Technology. This study was carried out through the following phases:

Preparation of samples: The collected teeth were cut into 5x5x3 mm slices with double-sided flex

diamond discs (Brasseler, Lemgo, Mini, Germany) under water and air spray in a way that sound tooth enamel was present in their outer surface. Outer enamel surface was then polished with fine and coarse diamond burs (D & Z, CE, Germany) with water spray and green and white composite polishing rubber points (Victory, Brazil) with no water for 30 seconds. Samples were then ground with silicone carbide abrasive papers (Kingcattle, USA) with 400 and 600 grits, respectively for 60 seconds to create micrometer-scale surface smoothness in order for the profilometer to be able to move over the surface. Slices were embedded in self-cure acrylic resin (Acropars 200 without cadmium, Marlic Medical equipment company, Tehran,

Iran) molds with 25 mm diameter and 6 mm thickness in a way that their surfaces were at the level of acrylic resin.



Figure 1- Profilometer

Measurement of initial surface profile of samples: After placing the samples in the profilometer the diamond stylus is moved vertically in contact with the sample and then moved laterally across the sample for 4 mm on a hypothetical line and the value for initial surface profile is displayed in micron. This measurement was done on two parallel lines with 2 mm distance from each other and the mean surface profile value of the two lines was considered as the initial surface profile in micrometer.

After measuring the initial surface profile, obtained values were arranged in an ascending order and one sample from each group was randomly selected and entered into the new classification. Four groups of 6 specimens each were created. This act reduced the difference in profilometry values in the groups.

Also, samples in groups were coded as A, B, C and D and the paths of movement of profilometry stylus and tooth brush (which were perpendicular to each other) were marked.

Abrasion of samples: Abrasion was done using the three-object method with the toothpaste, enamel and tooth brush with back and forth strokes of V8 cross brushing machine (Sabri

Enterprises, Downers Grove, IL, USA). Since the path of movement of profilometer has to be perpendicular to the path of abrasion, samples were positioned in the device with a 90° rotation based on the previous markings. Eight tooth brushes (soft G.U.M model 411 classic, made in USA) were placed in the machine and samples were fixed in their locations below the brushes. Twenty g of each toothpaste was dissolved in 40 ml water for 5 minutes and mixed with 10 ml sodium carboxymethyl cellulose 0.5% (as the artificial saliva) in special glass tubes and placed next to the brushes and samples in the form of a solution.

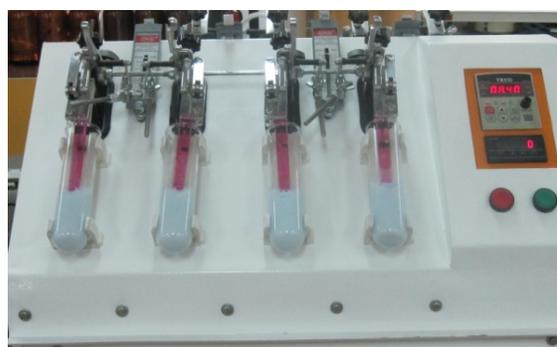


Figure 2. V8 cross brushing machine

This was a double blind study. Tooth brushes were adjusted to apply 130 gr force on samples with 15,000 strokes and a speed of 100 rpm.

Measurement of secondary surface profile: Samples were rinsed, air dried and placed in the profilometer with a 90° rotation in their baseline position. The mean secondary surface profile of each sample was measured again on the two hypothetical lines as described earlier for the measurement of initial surface profile. Data were analyzed using SPSS software, Repeated Measures ANOVA and one way ANOVA with significance level of 0.05.

Results:

Data regarding the mean initial and secondary profile values, their differences and standard deviations for each toothpaste are presented in Table 2.

Table 2- The mean initial and secondary profile values, their differences and standard deviations for each of the understudy toothpastes

Type of toothpaste	Mean initial profile value ± SD	Mean secondary profile value ± SD	Mean difference of initial and secondary profile values ± SD
Pooneh Whitening	1.01±0.46	1.69±0.39	0.68±0.33
Crest 3D Whitening	1.00±0.49	1.45±0.55	0.45±0.31
Sensodyne Original	1.01±0.54	1.49±0.82	0.48±0.36
Pooneh Anti-sensitivity	1.28±1.04	1.42±1.04	0.14±1.05

One way ANOVA failed to find a significant difference in the recorded profilometry measurements in the 4 groups before (P=0.86) and after (P=0.92) the abrasion. However, the four groups had statistically significant differences in terms of abrasiveness (difference in measurement before and after the abrasion)(P=0.039). Repeated Measures ANOVA was also performed and demonstrated significant differences in the values before and after the intervention (P=0.001). In other words, the secondary profile was significantly different from the initial profile. Also, these differences

were not the same in the 4 toothpastes (P=0.039). In fact, this analysis somehow confirmed the results of one way ANOVA. Paired comparison of groups with LSD test (least significant difference) revealed that the only statistically significant difference existed between Pooneh Whitening and Pooneh Antisensitivity tooth pastes (P=0.005). It should be mentioned that in some cases of paired comparison of groups, significant differences were not detected but the obtained value was close to the level of significance (borderline results)(Table 3).

Table 3- Paired comparison of abrasivity of toothpastes by the LSD test and P values

Pooneh Antisensitivity	Pooneh Whitening	Sensodyne	Crest 3D White	Type of tooth paste
Pooneh Whitening	0.193	0.224	1	0.005
Pooneh Antisensitivity	0.087	0.066	0.005	1
Crest 3D White	1	0.887	0.193	0.087
Sensodyne	0.887	1	0.224	0.066

This difference was especially observed in terms of the abrasivity of Pooneh antisensitivity with other toothpastes.

Discussion:

Composition of toothpastes has greatly changed since their introduction into the market. Nonetheless, the abrasive agent is the mostly fixed ingredient in the majority of toothpastes. Primary evaluation of samples with one way

ANOVA and lack of a significant difference in their initial surface profile (P=0.86) indicate the similarity of initial surface profile of the test samples which may be attributed to the preparation phases carried out for all samples. Based on the obtained results (P=0.039), the greatest abrasion occurred in the Pooneh Whitening toothpaste group while the lowest abrasion was seen in the Pooneh Antisensitivity toothpaste samples. The noteworthy issue is that both these toothpastes are Iranian made products. Additionally, the only statistically

significant difference in paired comparison of the four groups was observed between the two aforementioned Pooneh toothpastes. The two foreign made toothpastes of Sensodyne and Crest 3D White had almost similar abrasivity.

Different abrasivity of toothpastes depends on the hardness, size, shape and mass percent of the abrasive particles in the toothpaste (22). In this study, the abrasive agent present in all four toothpastes was silica. Also, Goltash company uses silica particles of the same size and shape for all its products. Thus, the difference in Pooneh Whitening and Pooneh Antisensitivity toothpastes can be attributed to the percentage of abrasive agent. A higher percentage of abrasive agents is used for Pooneh Whitening toothpaste while a lower percentage is incorporated into the composition of Pooneh Antisensitivity toothpaste.

Another point worth noting is presence of three whitening agents (tetrapotassium pyrophosphate, disodium pyrophosphate and tetrasodium pyrophosphate) in the Pooneh Whitening toothpaste. However, only one type of whitening agent (disodium pyrophosphate) has been used in Crest 3D white toothpaste. This may be the cause of high abrasivity of Pooneh Whitening toothpaste.

Another factor responsible for abrasivity of toothpastes may be the presence of various ingredients in the composition of toothpastes with different pH and subsequent increased or decreased abrasiveness of the paste. Ranjitkar et al, in 2009 demonstrated that use of some agents and lubricants in the composition of toothpastes and their percentage can affect abrasivity of toothpastes due to their lubricating property and reducing friction (23).

Recent studies have demonstrated that radioactive dentin abrasion (RDA) and profilometry are more accurate for evaluation of the abrasivity of toothpastes (24). Considering the high cost and inaccessibility of RDA method (25) especially in Iran, we were not able to use it in the present study. We used profilometry which is more accurate than measuring the mass loss of samples. Also, we have to add that profilometry is among the most popular methods used worldwide for abrasion studies (11). Its accuracy compared to other methods, and not damaging the surface during the measurement

are among the most important advantages of this method. No standard reference value has been set for the profilometry of toothpastes but the abrasivity of Sensodyne Original and Crest 3D White according to the RDA criteria is approved by the ADA and it may be a good idea to consider their profilometry value as an acceptable abrasivity index (26).

In-vivo clinical studies on tooth abrasion are almost impossible to conduct. Such studies are not feasible because of the need for patient follow up, multi-factorial nature of abrasion and not having fixed reference points in the oral environment (27-31). In some studies samples are made of composite or acrylic resins. It may seem that similar composition of samples is an advantage for reducing the confounding factors and reproducibility of the study. However, it should be noted that our goal, when selecting enamel, was to simulate clinical setting conditions as much as possible. Considering the high cost of profilometry study, we had to settle for the minimum requirements of an abrasion study which included:

1. Small sample size: A larger sample size would increase the possibility of obtaining different results and significant differences in the abrasivity of other toothpastes.
2. Small number of profilometry measurements of samples: In the majority of similar studies, number of profilometry measurements for each sample before and after the abrasion was more than 2 times. However, we were only able to do it twice for each sample. By increased number of profilometry measurements, more accurate results would be obtained.
3. Abrasion test was limited to a fixed number of strokes (15,000 strokes). In similar studies, researchers tried to start from lower number of strokes and then proceed to higher rates. Such studies have demonstrated that test results and their level of significance vary with different number of strokes.

Conclusion:

Based on the obtained results, no statistically significant difference exists between the two Iranian made toothpastes and the two standard foreign pastes in terms of causing enamel

abrasion. However, considering the statistically significant difference in the abrasivity of two Iranian toothpastes, future investigations with different assessment methods are required to further evaluate their abrasivity and effectiveness.

Suggestions:

For more accurate studies on this subject the following points have to be considered:

1. A larger sample size with a wider variety
2. Study of other toothpastes and preparing a databank on toothpastes

3. Performing abrasion tests with a higher number of profilometry measurements of samples
4. Study of samples with different abrasive strokes
5. Using other methods of assessing abrasion and erosion (like SEM) as an adjuvant to profilometry

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