Texila International Journal of Public Health
ISSN: 2520-3134
DOI: 10.21522/TIJPH.2013.11.03.Art005

Properties of Natural Materials as Alternative to Nylon Bristles – An Exploratory Study for Reduction of Polymer Usage

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Abstract

Background: Nylon bristles are the most commonly used type of bristle in toothbrushes, but they have both advantages and disadvantages. Nylon bristles can be too hard or abrasive for some people's teeth and gums. Nylon is not biodegradable and can harbor bacteria if not cleaned properly. Aims: In order to explore the possibility of using natural fibers this study was conducted. Materials and Methods: Twigs of neem, banyan, babool and miswak were purchased as fresh twigs, wiped clean, hammered on a hard wood base to obtain fibers of desired lengths. Physical appearance, Bend Recovery, Folding Endurance and Antibacterial adhesion against B. Subtilis were evaluated. All experiments were performed as triplicate and mean and standard deviation were reported. Results: Digital microscopy showed well defined fibers of fairly constant diameter, apparent from the superimposed scale. Results of bend recovery analysis showed that miswak fibers were flexible and recovery was good. Folding Endurance test showed miswak and banyan were having great folding endurance. Bacterial adhesion with B. Subtilis was heavy in all fibres. The antibacterial activity of four extracts showed that all groups had identifiable antimicrobial activity at 2000 µg concentrations. Conclusion: From results of the study, it can be inferred that miswak is the most suitable material to be used for fabricating bristles in its native form.

Keywords: *Babool, Banyan, Bristles, Natural Fibres; Neem Miswak.*

Introduction

The history of toothbrushes dates to ancient civilizations, where people used twigs, feathers, and animal bones to clean their teeth. The first toothbrush with bristles was invented in China during the Tang Dynasty in the 7th century. These early toothbrushes were made from hog hair or horsehair attached to bamboo or bone handles. In the 15th century, Europeans began using toothbrushes made from boar bristles attached to bone or ivory handles. However, it wasn't until the 1930s that nylon bristles were invented by Dupont de Nemours and introduced into toothbrush manufacturing. Toothbrushes have continued to evolve over time with

Received: 18.07.2023 ***Accepted: 21.09.2023*** ***Published on: 29.09.2023***

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advancements such as electric toothbrushes and more recently, smart toothbrushes that can connect to smartphones and provide real-time feedback on brushing habits. Today, there are a variety of toothbrush options available including manual and electric brushes with different bristle types and head sizes. Additionally, there are eco-friendly options such as bamboo brushes that are biodegradable [1].

The history of toothbrushes highlights the importance of oral hygiene throughout human civilization and how technology has continued to improve our ability to maintain healthy teeth and gums. Nylon bristles are commonly used in toothbrushes and other cleaning tools. The bristles of a toothbrush play a vital role in cleaning teeth and removing plaque and bacteria. Nylon bristles are the most used type of bristle in toothbrushes, but they have both advantages and disadvantages. One of the advantages of nylon bristles is that they are durable and long-lasting. They do not easily break or wear out, which means that you can use them for a longer time before needing to replace them. Nylon bristles also come in different sizes and shapes, making it easier to find one that suits your needs [2].

On the other hand, nylon bristles can be too hard or abrasive for some people's teeth and gums. This can cause discomfort or even damage to the enamel on your teeth [3]. Additionally, nylon is not biodegradable, which means that it contributes to environmental pollution when disposed of improperly. Another disadvantage of nylon bristles is that they can harbor bacteria if not cleaned properly. This can lead to infections in the mouth and other health problems. In contrast, natural bristle toothbrushes made from animal hair such as boar or horsehair are softer than nylon brushes but may not last as long. They also have antibacterial properties that help prevent infections in the mouth. They also tend to be more expensive than their synthetic counterparts [4].

In summary, while nylon bristle toothbrushes have their advantages such as durability and variety in size and shape, they may not be suitable for everyone due to their hardness. It is important to choose a toothbrush with soft enough bristles that will effectively clean your teeth without causing any harm or discomfort while considering its environmental impact when disposing of it properly.

However, most toothbrushes are made of plastic, which is not only harmful to the environment but also potentially hazardous to our health [5]. Fortunately, there are natural materials that can be used for toothbrushing that are not only eco-friendly but also beneficial for our teeth and gums. One such material is bamboo. Bamboo toothbrushes are biodegradable and sustainable as they grow quickly and require minimal water and pesticides. They also have antimicrobial properties that help prevent the growth of bacteria in our mouths. Another natural material is charcoal. Charcoal has been used for centuries as a natural teeth whiten and breath freshener.

It works by absorbing toxins and impurities from the mouth, leaving it clean and fresh. Lastly, neem twigs have been used in India for centuries as a traditional method of oral hygiene. Neem has antibacterial properties that help prevent gum disease and cavities while also freshening breath. Therefore, using natural materials for toothbrushing not only benefits our health but also helps protect the environment. By making a simple switch to a bamboo or charcoal toothbrush or using neem twigs, we can make a positive impact on both us and the planet.

During orthodontic treatment, brushes may encounter more than normal debris and flora owing to the reduced self clensibility due to presence of appliance. To make the toothbrush inherently antimicrobial in nature, silver nano or chlorhexidine has been coated on the brush, however, it has not been successful [6]. The need of the hour is hence a material, that can

discourage any pathogenic growth on the brush during and between brushings. To achieve that, there needs to be an understanding of the structure function relationship of the bristle material, which is largely unexplored. The adhesion of flora on the surface of the bristles is governed by surface physics and surface chemistry of the bristles. Chemical molecules and reactivity along with physical properties like adsorption and hydrophillicity affect or select the bacteria that adhere to them. Instead of disinfecting the used brush, is it prudent to use disposable toothbrushes? If so, what are the suitable materials? Currently used nylon is not biodegradable and will pose a major pollution hazard, so can't be advised. In order to reduce pollution at the same time use a good toothbrush with advantage of anti-inflammatory and growth promoting phytochemicals, can natural fibers be used? If natural fibers are used, are they efficient enough for plaque removal, conversely, are their properties like existing nylon brushes? To answer these questions, in this research 4 traditionally used twigs were selected for analysis of physical and mechanical properties.

The recent past has seen a significant use of herbal components in daily life and hence, it is proposed to include herbal fibers in brushing instruments. To explore the possibility of using natural fibers like neem (Azadiracta Indica), banyan (Ficus bengalensis), babool (Vachellia nilotica) and miswak (Salvadora persica) this study was conducted. Authors hypothesize the following:

1. Natural fibers have mechanical properties at par with nylon.
2. Natural fibers exhibit lower bacterial adhesion.
3. Extracts of these natural materials can be used as toothbrush disinfectant.

Materials and Methods

Twigs of neem (Azadiracta Indica), banyan (Ficus bengalensis), babool (Vachellia nilotica) and miswak (Salvadora persica) were purchased as follows: Neem (SHIV), Banyan (GPS ENTERPRISES), Babool (YOTOVA) and Miswak (AB World Class) purchased via Amazon.in. Thus, purchased fresh twigs were wiped clean with a dry cloth and hammered on a hard wood base to obtain fibers of desired lengths. Thus, obtained fibers were stored in airtight containers at 4^{o}C in refrigerators until used. This was done to maintain its moisture content.

Physical Appearance

The samples observed in digital microscope with a superimposed scale. The fibres were effectively visualized. (2 mm diameter fibres were magnified and viewed, thinner fibres were also shown since they were combined to make 2 mm diameter tufts)

Bend Recovery

The DuPont or mandrel method is relatively easy to do and gives very consistent results [7]. The basic test involves winding ten turns of the filament on a 3/32" (2.4 mm) diameter rod or mandrel. After the filament has been on the rod for four minutes, it is cut off and allowed to relax in a dish of water for one hour. The bend recovery is calculated based on the number of turns in the filament at the end of the recovery periods compared to the number of turns wrapped on the mandrel, expressed as a percentage. The test is modified as follows, the relaxation in water for 1 hour is omitted as it may change the properties of fibres and they don't remain in water for that duration for said application.

Folding Endurance

The folding endurance or flexibility of the film was determined by repeatedly folding the film at 180° angle of the plane at the same place until it breaks or folded to 300 times without breaking. The number of times the films folded without breaking as considered as folding endurance [8, 9].

Antibacterial Adhesion against B. Subtilis

B. subtilis was cultured in Mueller-Hinton broth and incubated for 24 hrs. The fibres of the said twigs were cut to 2 cm and immersed into the broth for 24 hours. Subsequently fibres were removed and washed with running sterile water for 3 mins. Then, they were blotted on sterile filter paper and placed in sterile Mueller-Hinton broth and incubated for 24 hours and plated in MH agar plates. Colony count was determined from the plate [6]. Since all the twigs showed huge number of bacterial adhesions, it is advisable to use as disposable brush only and cannot be stored for long time like nylon bristles.

Statistical Analysis

All experiments were performed in triplicate and mean, and standard deviation were reported.

Results

Figure 1. The Microscopic Image of Fibers Extracted from The twigs

Table 1. Bend Recovery of Fibers used in the Study

	Mean	**SD**	**Comments**
Miswak (x1)	4	1	fold remained
Babool (x2)	10	0	(No recovery at all)
Neem (x3)	0	0	(Not amenable for the folding, brittle and breaks)
Banyan (x4)	2	0	-
P Value (One way ANOVA)	5.962E-10 (Significant)	-	-

Table 2. Intergroup Comparison for bend recovery (Post hoc Tukey test)

Pair	**p-value**
x1-x2	3.437E-08
x1-x3	3.506E-07
x1-x4	4.263E-05
x2-x3	9.145E-10
x2-x4	5.45E-09
x3-x4	0.0001318

(x1 is Miswak; x2 is Babool; x3 is Neem and x4 is Banyan)

Table 3. Folding Endurance of Fibers Used in the Study

	Mean	**SD**	
Miswak (x1)	300	0	(more than 300 still not breaking)
Babool (x2)	133	28	-
Neem (x3)	56	23	-
Banyan (x4)	300	0	(more than 300 still not breaking)
P Value (One way ANOVA)	3.165E-07 (Significant)	-	-

Table 4. Intergroup Comparison for Folding Endurance (Post hoc Tukey test)

Pair	**p-value**
x1-x2	1.57E-05
x1-x3	8.814E-07
x1-x4	1
x2-x3	0.003703
x2-x4	1.57E-05
x3-x4	8.814E-07

(x1 is Miswak; x2 is Babool; x3 is Neem and x4 is Banyan)

Table 5. Antibacterial Activity of Extracts

Species	**B. subtilis**			**S. aureus**			**P. aeruginosa**			**E. coli**		
	µg	**µg**	**µg**	**µg**	**µg**	**µg**	**µg**	**µg**	**µg**	**µg**	**µg**	**µg**
Concentration	**500**	**1000**	**2000**	**500**	**1000**	**2000**	**500**	**1000**	**2000**	**500**	**1000**	**2000**
Neem	0	0	8(0)	0	0	8(0)	0	0	8(0)	0	0	8(0)
Banyan	0	0	8(0)	0	0	10(0)	0	0	10(0)	0	0	0
Babool	0	0	9.3(1.1)	0	0	10(0)	0	0	9.3(1.1)	0	0	9.3(1.1)
Miswak	0	0	8.7(1.2)	0	8.0(0.0)	10.0(0.0)	0	0	9.3(1.2)	0	0	9.3(1.2)
Control (20µg)	26(0)			22(0)			26(0)			28(0)		
Streptomycin												

Table 6. Comparative Activity at 2000ug Concentration

	B. subtilis	**S. aureus**	**P. aeruginosa**	**E. coli**	**p Value (One Way ANOVA)**
Neem	8.0(0.0)	8.0(0.0)	8.0(0.0)	8.0(0.0)	1
Banyan	8.0(0.0)	10.0(0.0)	10.0(0.0)	0.0(0.0)	0
Babool	9.3(1.2)	10.0(0.0)	9.3(1.2)	9.3(1.2)	0.8018
Miswak	8.7(1.2)	10.0(0.0)	9.3(1.2)	9.3(1.2)	0.4872
p Value	0.2192	0	0.08545	1.621E-06	-

Discussion

On the market, there are numerous toothbrushes with various bristle designs. Brushes are classified as soft (0.2 mm), medium (0.3 mm), or hard (0.4 mm) based on the diameter of the bristles [10]. Brush bristles differ in size and design, as well as length, hardness, and arrangement. The stiffness of bristles can differ according to their diameter, length, the number of filaments in a tuft, along with filament curvature [11].

Flat trim design, zig-zag pattern, and bi-level bristles are some of the most common bristle designs available in the Indian market. Surface abrasivity can be affected by toothbrush bristle

design. Bass [12] recommended that each filament be end-rounded to minimise trauma when describing the ideal characteristics of a toothbrush. Following clinical trials, Hine [13] discovered that the shape of the ends of nylon filaments is unimportant and that round-ended bristles are no safer than cut-ended bristles. However, many dentists still recommend using round bristle tips because they cause fewer traumas than sharp-edged bristles [14]. For a soft brush the tuft diameter is 2 mm. So approximately 2 mm diameter fibers were removed from the beaten twigs and mechanical analyses were conducted.

The samples observed in digital microscope showed well defined fibers of constant diameter, apparent from the superimposed scale. Previous authors have reinforced these fibers such as that of miswak with polymers such as poly lactic acid for use as toothbrush handles [15]. Similar works have been done in neem and banyan fibers also [16] Babool fibres have been seen as good source of strong cellulose and hence used for the said purpose [17]. However, literature is scarce regarding visualization of fibers in pristine form. This work has attempted to do the visualization using digital microscopy.

Bend recovery is an important property required for a material to be used as bristles. During the usage the bristles bend for every stroke during a single brushing session. High amount of bend recovery is necessary to maintain the original shape as well as to have a good cleaning action. Nylon fibers have a good bend recovery for multiple brushing sessions. It is necessary to test natural fibers for the bend recovery to determine its usage as a bristle. Results of bend recovery analysis are shown in the table below. The miswak fibers were flexible and recovery was good. However, babool had no recovery, showing its unsuitable nature for use as bristle material in the pristine form. Neem did not bend at all, showing its hard and unsuitable for usage in native form. Banyan had moderate recovery, but lesser than miswak, showing miswak is the most suitable fiber as suggested by the bend recovery analysis.

With regard to Folding Endurance, the property of the fiber to withstand folding is essential to fabricate it into a brush form. After fabrication to a bristle, folding endurance is needed to protect the bristles during storage. The biomechanical deformation of nylon may differ from natural materials. In this study, miswak and banyan showed great folding endurance followed by babool and neem. Therefore, miswak and banyan are recommended from this test.

With regard to Antibacterial adhesion against *B. Subtilis*, the immersion of fibers in broth leads to adhesion of bacteria to natural fibres. The idea behind this analysis is to see if the fibers can resist bacterial adhesion. However, the result of the analysis was negative. Since all the twigs showed a huge number of bacterial adhesions, it is advisable to use as disposable brush only and cannot be stored for long time like nylon bristles. However, this does not increase the pollution as nylon does, therefore, it does not go against the ideology of reducing the carbon footprint.

The antibacterial activity of four extracts showed that all groups had identifiable antimicrobial activity at 2000 µg concentrations. However, mild variations in clearance zone were seen. Among the same bacterial species, no variation in clearance zone was observed, except in E. Colias banyan had no activity against E. Coli. With respect to plant species, there was variation in activity against various bacterial species in neem and banyan. However, miswak and babool had similar clearance zones against all bacterial species.

From results of the study, it can be inferred that miswak is the most suitable material to be used for fabricating bristles in its native form. As bacterial adhesion test showed poor results for all twigs, it can be concluded that disposable single usage bristles are currently feasible to be produced. With respect to

preparation of disinfectants for currently used brushes, miswak extract is recommended.

Researchers discovered a number of natural bioactive components in Salvadora persica extracts. These components are thought to be necessary for good oral and dental sanitation. Salvadora persica has significant antimicrobial activity against aerobic and anaerobic bacteria. According to Al-Bayati and Sulaiman [18], an aqueous extract of Salvadora persica was successful against all pathogens tested. According to an in vitro study, it has potent antibacterial properties against bacteria associated with periodontitis and caries advancement [19]. Almas and Al-Zeid [20], discovered that miswak significantly reduced Streptococcus mutans more than tooth brushing, but there were no significant differences in Lactobacilli reduction. In an in vitro study, Elangovan et al [21] noticed that aqueous extracts of neem (Azadirachta indica) had the best antimicrobial activity against Streptococcus mutans, while the miswak extracts had the best antimicrobial activity against Lactobacillus acidophilus. In a pilot and cross-sectional study of adults in Ghana, Norton, and Addy [22] discovered that miswak users experienced a reduced rate of plaque formation, growth, and advancement of caries than those who used artificial toothbrushes. Gazi et al [23] discovered that using a miswak five times per day compared to a conventional toothbrush resulted in a substantial decrease in gingivitis. When combined with professional instruction on how to use it correctly, Al-Otaibi et al [24] discovered that the miswak is more effective than tooth brushing at decreasing plaque and gingivitis.

Conclusion

With regard to hypotheses of the study, the first hypothesis that “Natural fibers have mechanical properties at par with nylon” is accepted as mechanical properties were comparable. The second hypothesis that “Natural fibers exhibit lower bacterial adhesion” is summarily rejected as all twigs showed high amount of contamination. The third hypothesis that “Extracts of these natural materials can be used as toothbrush disinfectant” is accepted and further studies are needed to optimize the quantum and concentration of extract.

Future Scope of the work should be directed against preparation of disposable bristles mounted for use in regular and orthodontic use. In another direction, toothbrush disinfectant can be manufactured by mixing these phytochemicals for synergistic action.

Conflict of Interest

There is no conflict of interest.

Acknowledgement

The authors thank Dr. S. Rangachari, retired professor of Orthodontics, Madras Dental College for kind encouragement and guidance.

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