Original Article

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Strength of disposable floss holders: A new test model of applying vertical force to dental floss

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Objective: To compare strengths of seven disposable floss holders, which were five F-shaped and two Y-shaped, by applying vertical force to floss attached on each holder.

Materials and Methods: This study employed an experimental design. Each floss holder was held on the dental stone platform while testing was conducted, using the Instron universal mechanical testing machine. This machine exerted the force vertically at the mid length of the dental floss until the floss was torn or pulled out. The failure force that caused tear or pull-out of the dental floss was recorded. The data was then analyzed statistically with Kruskal-Wallis test and Tukey's multiple comparison (α=0.05). Weibull analysis was also performed. Moreover, the percentage of the failure characteristics of the floss holder were recorded.

Result: All types of floss holders passed the strength test at 11 N as recommended by Dörfer et al. in 2001. The failure characteristics were dental floss pull-out of the holder (F1, F2, F4, Y1, Y2). There were statistically significant differences ($p<0.001$) between the maximum force in the F3 group and almost all other groups except the F5 group. The F3 group showed the maximum strength and Weibull modulus at 46.64 and 14.98, respectively. The F2 group, despite passing the strength test, showed the minimum strength consistency (Weibull modulus of 4.79).

Conclusions: To summarize, all dental floss holders passed the standard; F3 group showed the maximum strength, while the F2 group had the least strength consistency. Overall, the connection between dental floss and floss holder plays the key role determining the strength of this appliance.

Keyword: dental floss, floss holder, interdental cleaning, plaque removal, strength test

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Introduction

Caries and periodontal diseases are most common oral diseases, which can be prevented by proximal plaque removal [1-3]. Previous study found 50 percent reduction of proximal caries after use of dental floss by dental personnels for a period of 20 months [4]. Although smooth surface plaque removal reduced proximal bleeding up to 35 percent, tooth brushing incorporated with flossing boosted the reduction of proximal bleeding to 67 percent [5]. Although a proximal plaque control is considered essential and effective, dental floss requires a proper practical skill to use it.

Currently, there seem to be three main flossing methods, which are 1) wrapping around fingers, 2) tying floss into loop, and 3) using a floss holder. The first and second methods tend to be more suitable for healthy individuals who can floss efficiently after being instructed. Although flossing is certainly required for good oral hygiene, patient

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compliance is quite low [6]. Probably due to ease of use, the latter method, dental floss holders may promote the compliance of flossing in patients. In addition, previous studies demonstrated that plaque removal by using the floss holder technique showed the same efficiency of plaque removal and gingival index outcome when compared to the manual one; besides, most patients preferred using dental floss holders [7, 8]. Additionally, Carter-Hanson, et al. [9] supported efficiency of plaque removal using floss holders (Quik Floss®) and reinforced this holder use for handicapped patients. Moreover, for the elderly or patients with limited control of hands and fingers, floss holders can play an important role. Not only patient factors drive the need of floss holder use, orthodontic bracket and archwire also hinder the use of wrap around finger flossing. Orthodontic patients require the use of dental floss, and floss holder could make it considerably easier to clean proximal plaque in patients with orthodontic brackets [10].

At this stage, there is a scarce of systematic quality test of floss holder. Wolff and Staehle [11] tested the mechanical strength of 19 brands of floss holder by pushing the floss through proximal contact. Most of the floss holders withstood the force of 11 N, whilst only one brand withstood the force of 2.6 N. Dörfer et al. [12] also showed that the maximum force for dental floss to enter proximal contacts was 8.41 ± 3.45 N, and it was higher than the force at removal (3.14 ± 0.86 N). Furthermore, while ISO outlined the test model for the floss holder using weight hanging from the floss, this test model may reflect the force at pulling out. Therefore, the aim of this study was to compare strengths of different disposable floss holders, using a new test model of applying vertical force to dental floss on each holder.

Materials and methods

Survey of floss holders in the market

Dental floss holders were categorized into three main groups, which were 1) reusable floss holder, 2) disposable floss holder, and 3) powered flossing devices. Based on Thai market, most floss holders were disposable floss holders. Therefore, all constantly available disposable floss holders in Thai market were collected and put into this test model.

For a period of five months, five surveys were conducted at five leading department stores in Bangkok (Thailand) to retrieve all available disposable floss holders. Only products that were available in every survey were included. Seven disposable floss holders met the criteria. They were classified into two groups by the shape of the holder, which were F-shaped and Y-shaped types as showed in **Fig. 1** and **Fig. 2**. The length of the floss was measured using Digimatic Digital Vernier Calipers (Absolute Digital, Model CD-15CW, Mitutoyo Corporation, Japan), which their lengths are presented in **Table 1**. The mid length of the floss was also marked to be used as a point of force activation.

Floss holder platform design

In order to maintain a floss holder firmly during the test, a platform was designed customarily for each brand individually using dental stone. These individually designed platforms must firmly hold the floss holder to lie flat. Simultaneously, the floss was held parallelly to the base of the testing machine. The platform was newly designed to hold the floss holder at both holder and bow parts, compared the former design where only a holder part was held. To hold the floss holder firmly, at least half of the bow should be contained in this platform. The examples of these platforms were showed in **Fig. 3**.

Figure 1 Five types of F-shaped floss holders from left to right: F1 group - Dr.PHILLIPS Helping Hand Floss-Ups®; F2 group - Hand Held Flossers®; F3 group - Watsons Round Thread Dental Flossers Pick®; F4 group - Love the Value Dental Floss Picks® (Thookjai Daammaikudfun); F5 group - Home Fresh Mart Charcoal Dental Flossers®

Figure 2 Two types of Y-shaped floss holders from left to right: Y1 group - Dr.PHILLIPS Helping Hand Floss-Pick®; Y2 group - Hand Held Flossers®

Table 1 Disposable floss holders available in Thai market included in this study

Group	Shape	Trade name	Retailer and/or Importer, Manufacturer and country of origin	Length of floss (mm)
F1	F	Dr.PHILLIPS Helping Hand Floss-Ups®	Emporium Department Store, Tego Dental and Chemical Co.,Ltd., Dentex, Taiwan	13.58
F2	F	Hand Held Flossers® (standard size)	Boots Retail(Thailand) Ltd., Tego Dental and Chemical Co.,Ltd., Dentex, Taiwan	16.08
F3	F	Watsons Round Thread Dental Flossers Pick®	Central Food Retail Co.,Ltd., Dogguan Best Smile Co.,Ltd. China	13.24
F4	F	Love the Value Dental Floss Picks® (Thookjai Daammaikudfun)	Central Food Retail Co.,Ltd., Pingguan Network Co.,Ltd., Thailand	14.46
F5	F	Home Fresh Mart Charcoal Dental Flossers®	Home fresh mart, The Mall Department Store Pingguan Network Co.,Ltd., Thailand	15.56
Y1	Y	Dr.PHILLIPS Helping Hand Floss-Pick®	Emporium Department Store, Tego Dental and Chemical Co.,Ltd., Dentex, Taiwan	15.50
Y2	Y	Hand Held Flossers® (large size)	Boots Retail(Thailand) Ltd., Tego Dental and Chemical Co.,Ltd., Dentex, Taiwan	14.79

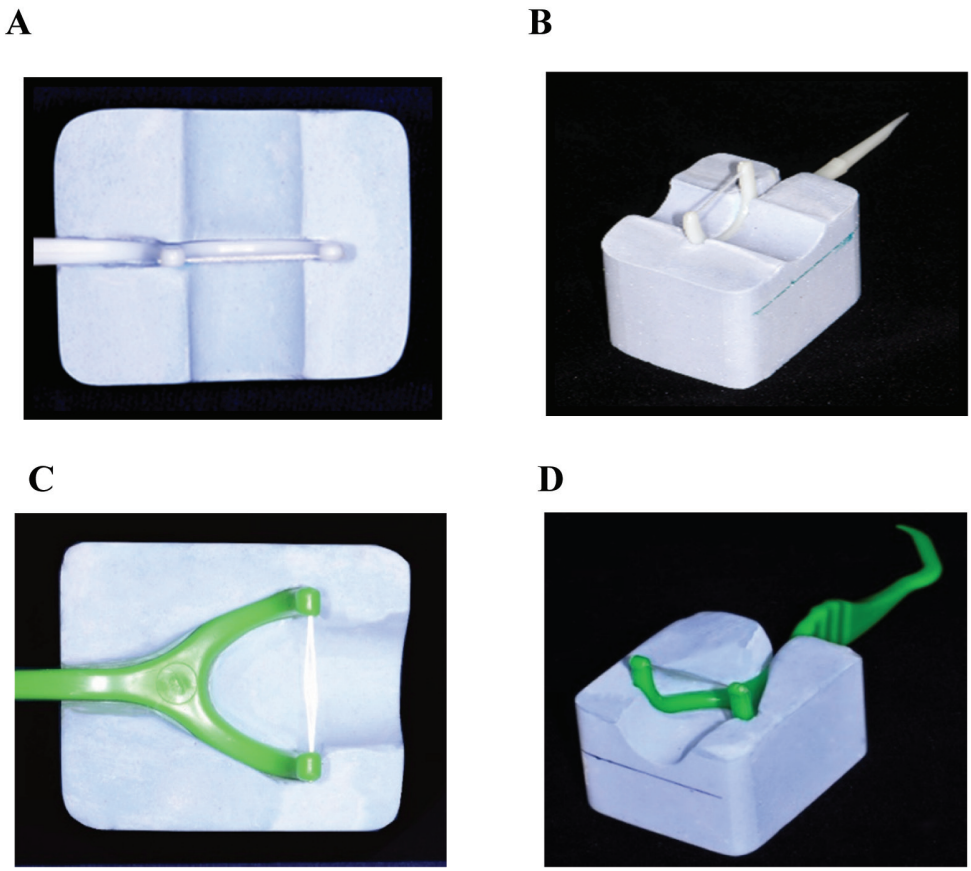

Figure 3 Floss holder platform design. A) F1 type floss holder platform (top-view) B) F1 type floss holder platform (perspective view) C) Y type floss holder platform (top-view) D) Y type floss holder platform (perspective view)

Strength test of the floss on floss holder

The platform with the floss holders were placed on the Instron universal mechanical testing machine (Instron 5566, Instron Corporation, England). Thirty pieces of each brand were tested with the blade of the loading apparatus placed onto the mid length of each dental floss (Fig. 4). The loading apparatus exerted the floss vertically down towards the dental floss until the dental floss was torn or came out of the floss holder. Compared to applying a pull force, this technique could prevent a bend of a floss holder. The pattern of failure and the amount of force exerted were recorded.

Statistical analyses

Kruskal-Wallis test and Tukey's test were applied to compare strengths of floss attached on different floss holders. The null hypothesis was that there were no differences between the strength of floss on different floss holders. In addition, Weibull analysis was used to analyze all data of failure.

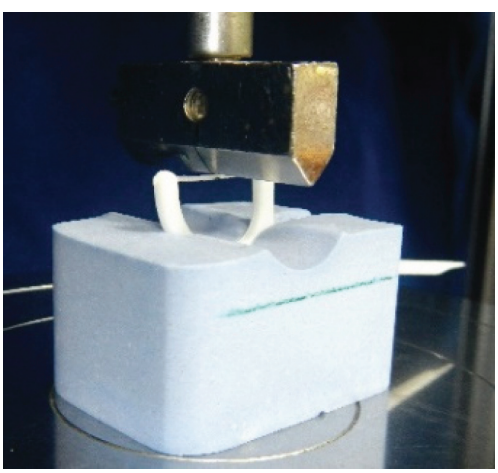

Figure 4 The setting of the utilization of the Instron universal mechanical testing machine

Results

There were two types of failure characteristics of the floss holder appliances, which were dental floss pull-out from the holder and tear of the dental floss, as shown in Fig. 5. According to Table 2, the percentage of these failure patterns were presented. Almost all failures (90 percent) of F3 group were tear of the dental floss itself. This was followed by the F5 group with 40 percent of the failures were dental floss tear. All failures of other groups (100 % of F1, F2, F4, Y1, and Y2 groups) were dental floss pull-out of the holder.

According to Table 3, the findings demonstrated force, characteristic strength, and Weibull modulus of each floss holder. Each floss holder passed the strength test at 11 N as proposed by Dörfer et al. [12]. The F3 type showed the maximum mean strength (44.99 ± 3.24 N), while the Y2 group showed the lowest strength (22.69 ± 4.79 N). The force exerted was tested and showed non-normal distribution. Kruskal - Wallis test and Tukey's test demonstrated that there were statistical differences ($p<0.001$) between the maximum force in the F3 group and other groups except the F5 group. Overall, there were statistically significant differences between the strength of floss on floss holder when the different types were compared. The F3 group showed the maximum strength and Weibull modulus at 46.64 and 14.98, respectively. The F2 group, despite passing the strength test, showed the minimum Weibull

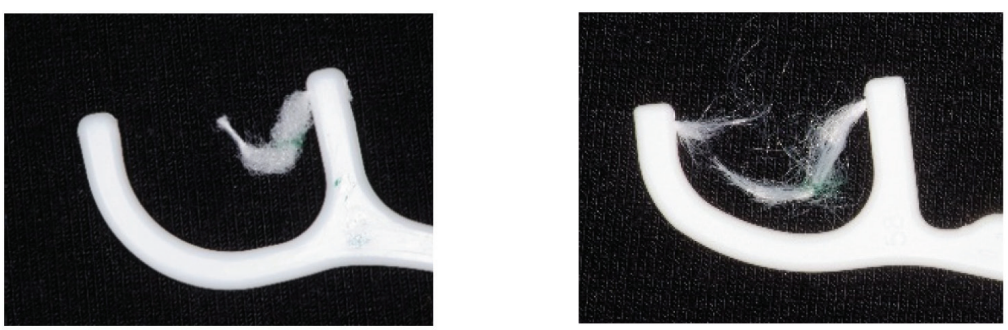

Figure 5 Failure characteristics of the floss holder appliances: A) Dental floss pull-out of the holder; B) Tear of the dental floss.

Table 2 Number of failure characteristics indicating pull-out of the flosses from the handles or tear of the flosses

Group	Shape	Amount of dental floss holders (%)	
		Floss pull out	Floss tear
F1	F	30 (100)	0
F2	F	30 (100)	0
F3	F	3 (10)	27 (90)
F4	F	30 (100)	0
F5	F	18 (60)	12 (40)
Y1	Y	30 (100)	0
Y2	Y	30 (100)	0

modulus of 4.79. Since Dörfer et al. [12] recommended the maximum force for the dental floss at 11 N, the probabilities of failure at this specific strength level (the Weibull modulus and characteristic strength) were calculated (see Fig. 6). The probabilities of failure at 11 N were almost insignificant in all groups; the failures of Y2, Y1 and F2 group were only 1.7, 0.8 and 0.3 percent, respectively. All other probabilities of failure were no more than 0.01 percent.

Table 3 Force (N), characteristic strength and Weibull modulus of different floss holders

Group of floss holder	N	Mean±SD (N)	Median (N)	Characteristic strength	Weibull Modulus
F1	30	29.38 ± 3.58 a,b	28.71	30.96	9.26
F2	30	33.97 ± 6.08 b,c	35.31	37.32	4.79
F3	30	44.99 ± 3.24 d	45.58	46.64	14.98
F4	30	33.18 ± 4.46 b,c	34.26	35.23	7.89
F5	30	37.73 ± 5.56 c,d	38.85	40.14	7.55
Y1	30	25.67 ± 5.50 a	25.93	27.91	5.14
Y2	30	22.69 ± 4.79 a	22.07	24.68	5.14

The mean difference was significant at the 0.05 level.
Same letters indicate no significant difference from each other.

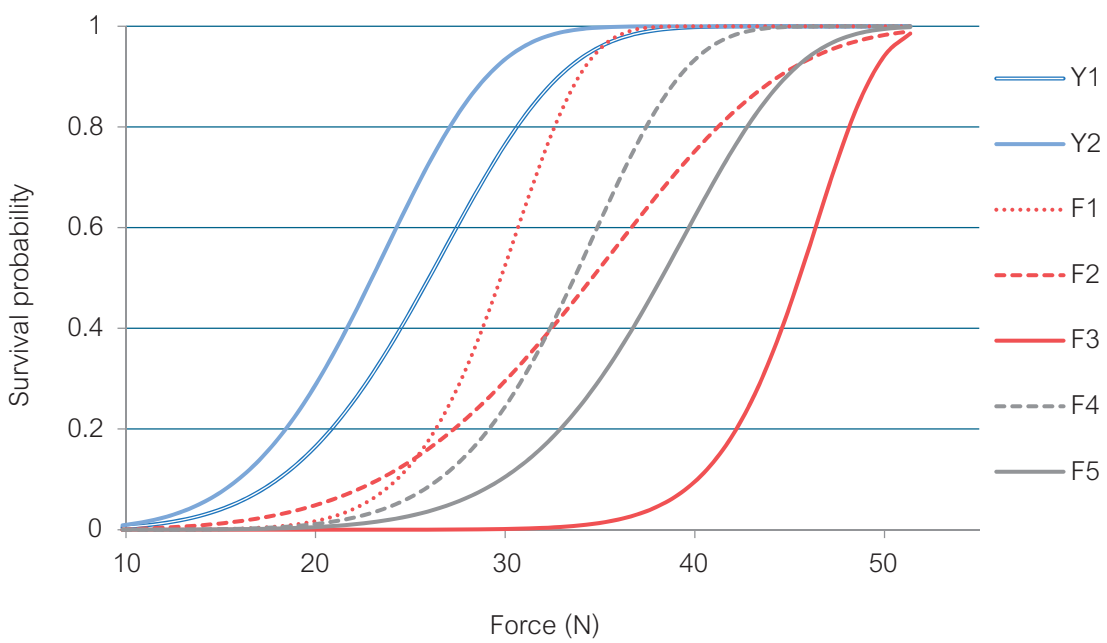

Figure 6 Weibull survival probability line.

Discussion

Floss holder quality assessments have been debated due to specific contributing factors such as floss holder morphology and functional factor of proximal tooth contact which could be greatly varied. Characteristics of the dental floss can affect floss holder strength, and thus they influence user preferences. Likewise, dental floss materials are diverse. They can be mono-fiber and poly-fiber, which the latter one can be divided into the twisted or stacked type [12]. Moreover, the shape and coating of the floss affect its gliding capacity. All of these factors could also impact the strength of the dental floss [12, 13]. However, from this study, the strength of the joint of the floss holder and dental floss in most groups mainly affected the strength of this appliance. While all types passed the standard of Dörfer et al. [12], the F3 type showed the maximum strength (44.99 ± 3.24 N) which was nearly 4.5 times of their recommended standard. While the strength of the Y2 group was the lowest, it was still twice the value of the Dörfer et al.'s standard [12]. In addition, most testing subjects had the floss torn out from the floss holder. In the F3 and F5 groups, when dental floss stayed intact with the holder, the subjects were further tested at higher force level to investigate the tear strength of the floss.

Furthermore, Weibull analysis was used to analyze the strength test, as the probability of survival was more suitable to describe the strength of the floss and floss holder. In addition to arithmetic mean, the probability of survival and Weibull modulus were evaluated. The Weibull analysis showed the characteristic strength and the Weibull modulus at 46.64 and 14.98, respectively. The characteristic strength characterized the 63.2 percentile of the strength distribution, which defined the force at which 63.2 percent of the units would have failed [14]. In addition, Weibull modulus is the slope of the Weibull plot that is used to describe the variation in the strength or asymmetric strength distribution as a result of flaws, which may develop within the microstructure [15]. It indicates the class of failure. Therefore, the higher Weibull modulus may indicate a more reliable system [16]. According to the F2 group, while it passed the strength test, it showed the minimum strength consistency (Weibull modulus of 4.79). This lowest strength consistency demonstrated the least consistency of the strength reliability.

To be more explicit and understandable, the probabilities of failure at standard 11 N set by Dörfer et al. [12] were calculated to show the percentage of floss holder failure at this standard. The probabilities of failure were almost insignificant in all groups. In other words, only 1.7 percent of the Y2 group would have failed when they were applied with 11 N forces. This means that the Y2 group showed 98.2 percent survival at this standard. Likewise, the Y1 and F2 groups demonstrated the 99.2 and 99.7 percent pass, respectively. The other groups also passed this standard with at least 99.99 percent survival.

The failure in pull-out of the flosses from the handles or tear of the flosses depend on a variety of factors. Not only floss factors (diameter of dental flosses as well as number and type of filaments) but also type of floss holders can influence those failures. Comparing between Y-type and F-type floss holders, the diameter (thickness or width) of the bow end in the former one is smaller than the latter one. As a result, the length of dental floss attached to the bow end in shorter in the Y-type, compared to the F-type floss holder, and therefore this could affect the failure characteristic. In addition, standards of manufacturing processes should be considered for both dental floss and floss holder selection.

This test was only conducted at the working end of the floss holder. To serve the use for special patients such as the elderly, handicapped and orthodontic patients, innovation of its handle was also required. Therefore, it would also be interesting to assess the strength of the handle.

Conclusions

Although an assessment of the floss holder quality can be perplexing due to multiple factors involved, well controlled systematized test could provide meaningful outcome. To summarize, all dental floss holders undergone this systematic test passed the standard, with the F3 group showed the maximum strength and the F2 group showed the least consistent strength. In this study, the connection between dental floss and floss holder played an important role in determining the strength of this appliance. Although the design of this study was already systematically considered, the test was performed only on the floss side. Further study on a handle is recommended.

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