MISCELLANEOUS

THE OPTIMUM CHARACTERISTICS OF DENTAL FLOSS FOR PERSONAL ORAL HYGIENE*

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Both caries and periodontoclasia, the two diseases from which almost all loss of teeth results, can be prevented by effective personal oral hygiene. Except for some advanced-stage lesions and some unusual conditions, control and prevention of further progress of these diseases, after they have started, can be secured in the same way. These two diseases cannot be thus prevented and controlled by any other practical method now known.

Any person, to prevent the initiation and further progress of caries and periodontoclasia, must clean his teeth right, every night before retiring. If he also cleans them at other times, this contributes to greater personal oral cleanliness.

The only way now known whereby one can clean his teeth well enough to prevent caries and periodontoclasia, and to maintain decent oral cleanliness, is by the proper use of the right kind of both toothbrush and dental floss. The functions of dental floss and the specifications of floss necessary for the best results, are presented here. In a companion paper[1] the functions of the toothbrush and specifications for the most effective and most appropriate brush are presented.

FUNCTIONS OF DENTAL FLOSS

Proper use of dental floss is necessary to clean the considerable area on the proximal surfaces of teeth, which cannot be reached by the bristles of the toothbrush. Proximal caries occurs at and around the contact point in these areas. In the early stage there is only partial decalcification, giving rise to the "white spot" which, at first, is microscopic in extent, but it gradually increases, if the etiological conditions are prolonged. As the lesion extends and enlarges, and as the decalcification process is continued, sooner or later the enamel breaks down and a cavity develops. This is the more advanced stage of caries.

Substantiating similar observations of others, I have shown[2] that the film of bacterial material beneath which caries begins and progresses consists

*Studies pursued in facilities in which the author has had access at the School of Medicine, Tulane University of Louisiana, and by aid for equipment and supplies provided by the University.

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principally of filamentous types of organisms. One end of the organism is attached to the enamel cuticle from which it extends outward toward the surface of the film. The deeper part of this bacterial film is a compact mass of more or less parallel microorganismal filaments radiating from the surface of the enamel. At the outer surface of the film there are the growing ends and fruiting heads of these filamentous organisms, among which there are numerous other organisms of many varieties from the oral cavity.

The chewing and masticating process thoroughly and heavily inoculates food material with the great variety of bacteria in the saliva, which are derived from all of the different surfaces within the mouth. Such inoculated food material, when lodged and retained upon the continuously present filamentous bacterial pad, is rapidly decomposed, not only by the bacteria from the saliva which is mixed with the material, but also by the growing microorganisms at the surface of the pad. If favorable carbohydrates are present, acids are produced. It has been shown[3, 4] that the application of sugar solutions to the bacterial pad ("materia alba") is quickly followed by marked increase in acidity.

Acids produced at the surface of the film are taken up and carried, as if by a sponge or wick, down to the surface of the tooth where they attack the enamel. Continuation and frequent renewal of these conditions, although microscopic and microchemical in nature, result in the early white spot stage of caries, and ultimately the later cavity stage. The purpose of the use of dental floss, so far as caries and personal oral cleanliness are concerned, is (a) to dislodge and remove any decomposing food material that has accumulated at the proximal surfaces since the previous cleaning and which cannot be reached and removed by the brush, (b) to dislodge and remove as much as possible of the growth of filamentous and other organisms that has accumulated in these protected caries susceptible areas, since the previous cleaning.

The lesion of periodontoclasia begins at the gingival margin and is initiated by the irritation and inflammation (microscopic at first) of the marginal gingival tissue by compacted and encrusted bacterial material on the enamel cuticle. Normally the marginal gingival tissue rests upon the soft, smooth, nonirritating enamel cuticle.[5] When, however, any rough hard material is superimposed upon the cuticle, it acts as a mechanical irritant like a foreign body. Once this hardened incrustation is established the resulting inflammation and exudation tend to promote its continuation and extension. Lime salts are deposited. Gradually the calculus and the overlying bacterial film impinge more and more upon the inflamed gum which recedes as the disease progresses.

In the further advanced lesion, on one side there is an inflamed suppurating surface of epithelial tissue, extending from the gingival margin

down to the very bottom of the lesion, where is located the outer border of the epithelial attachment and the zone of disintegrating epithelial attachment cuticle.[6] On the other side is the tooth on which there is more or less rough hard calculus to which is attached, and to the tooth around it, a

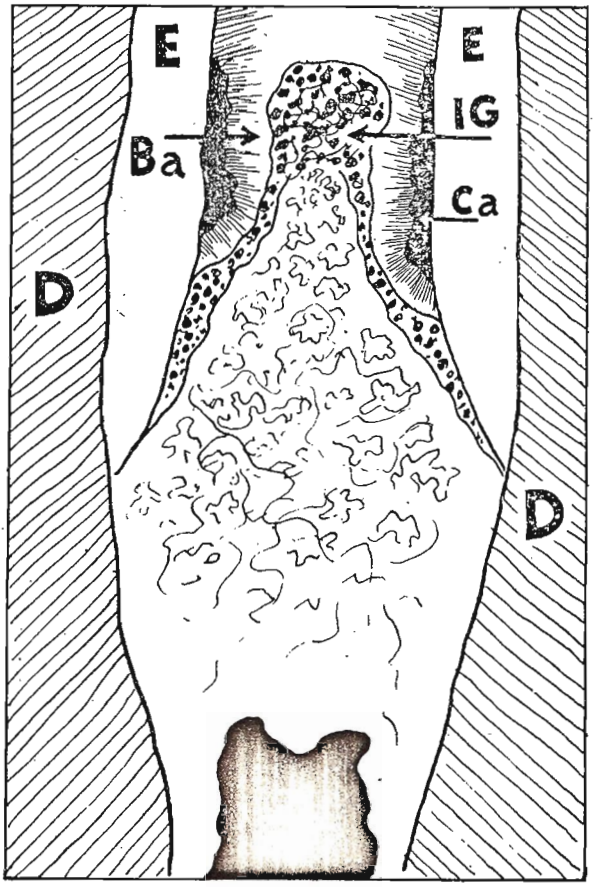

Fig. 1. Crude drawing to illustrate location of foreign material (concretion and bacterial) on the proximal surfaces of teeth within the gingival crevices. The area can be cleaned only by the use of the right kind of dental floss; D, dentin; E, enamel; Ca, calculus; Ba, bacterial film; IG, interproximal gingiva

pad of soft bacterial material consisting of a compact mass, of variable thickness, of stems and filaments extending outward toward the space ("pyorrhoea pocket") and downward toward the very bottom of the lesion (Fig. 1). The outer portion of the pad attached to the tooth within the lesion, consists largely of radiating filaments which protrude at the

surface as a thickset carpet-like pile of growing, branching and fruiting stems of leptotrichia, among which there are large numbers of other micro-organisms.

The purpose of the use of dental floss, so far as periodontoclasia and personal cleanliness in this location are concerned, is (a) to dislodge and remove any food material that has accumulated at the gingival margins, and in the gingival crevices between the teeth, since the previous cleaning and

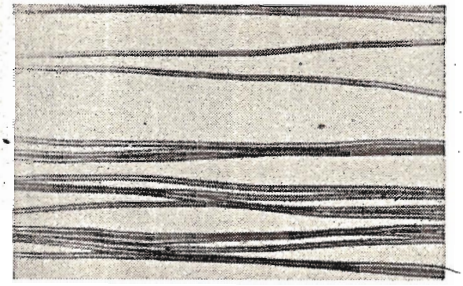

Fig. 2. Two denier nylon filaments showing uniformity of size and shape

which is not removed by the brush, (b) to dislodge and remove as much as possible of the growth of bacterial material upon the tooth or the superimposed calculus, that has accumulated there since the previous cleaning.

Keeping clearly in mind the functions for which dental floss is to be used relative to caries, periodontoclasia and personal cleanliness, we may proceed to consider the characteristics of floss that will be most effective for the purpose.

NYLON MOST FAVORABLE MATERIAL

Before the recent war the best material available, and the most widely used for dental floss, was silk. During the war silk became unavailable and synthetic substitutes were tried. All of these were quite unsatisfactory. Nylon was not available for this purpose during the war but it has been taken up by manufacturers since and is now quite generally used in place of silk. Nylon is so far superior to silk for dental floss for personal use that the latter is not likely ever to be used for this purpose in the future.

There are several advantages of nylon over silk—nylon can be made of uniform high quality whereas there is considerable variation in the quality of different lots of silk through trade sources; the individual filaments of nylon are cylindrical, smooth and uniform in size (Fig. 2) for the selected type, whereas those of silk are irregular in size and shape; nylon can be supplied with filaments of whatever size is found to be best for the pur-

pose; the tensile strength of high tenacity nylon is somewhat greater than that of silk; the abrasion resistance of nylon, when drawn over rough surfaces, is considerably greater than that of silk; the elasticity of nylon is greater than that of silk, allowing it to pass through close places and

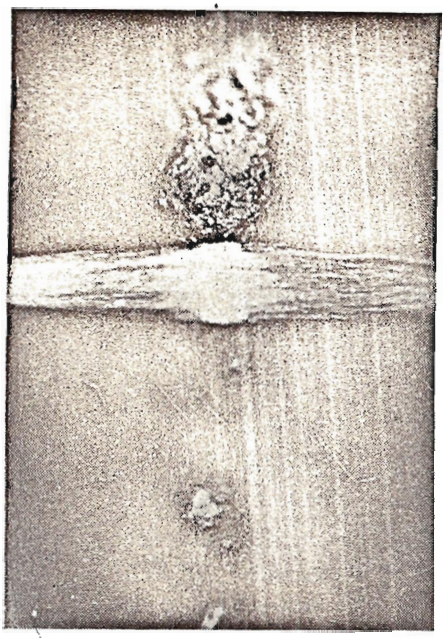

Fig. 3. Nylon floss, 350 denier, drawn over surface of tooth (stained for contrast). Note how it flattens and spreads

over rough surfaces with less filament breakage. The filaments in nylon yarn are continuous and free from loose ends whereas silk may have loose ends. This is especially objectionable in the low twist floss, without wax or size, which our studies have shown to be necessary for most effective use. The twist in the desirable low twist nylon floss can be set by steaming whereas objectionable size or wax would be required for silk.

"The term 'nylon' refers to a 'family' of chemically related products and is a 'generic term' for any long-chain synthetic polymeric amide which has recurring amide groups as an integral part of the polymer chain."* There are two kinds of "66" nylon yarns made today—normal and high tenacity yarns. Only the high tenacity yarn should be considered for dental floss.

*The author wishes to thank J. D. Zerbe, Jr., Technical Service, Nylon Division, E. I. du Pont de Nemours and Co., Wilmington, Del., for much helpful technical information and for generously supplying samples of nylon yarn.

It has higher tensile strength, greater abrasion resistance and adequate stretchability. High tenacity nylon yarns have a tenacity of 6 to 7 grams per denier† and an elongation, before break, of approximately 15 to 20 per cent.

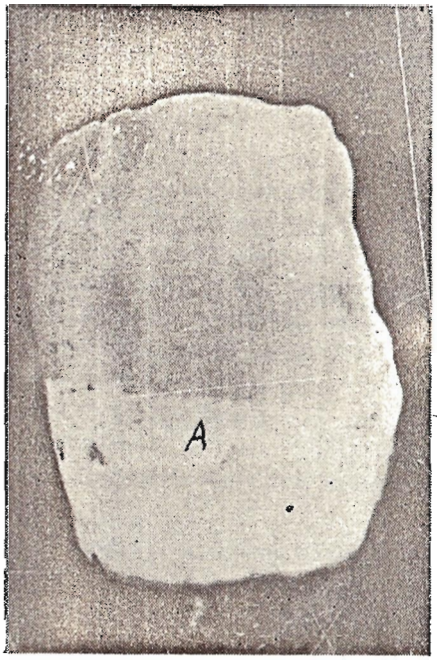

Fig. 4. Crown of extracted tooth across which waxed dental floss was drawn. The tooth was then stained lightly. Note lighter strip A, where the wax prevented staining

OBJECTIONS TO WAX OR OTHER SIZE

A piece of nylon dental floss is composed of a large number of separate, very small, somewhat elastic filaments. When it is drawn over an object like the surface of a tooth, the position of the filaments, with relation to each other, is adjusted according to the force or pressure applied to the different filaments. The filaments spread out and the round string tends to flatten out and widen (Fig. 3). Such a flattened string composed of many loose nylon filaments, when drawn either crossways or obliquely against a surface covered with bacterial film or other microscopic material, dislodges and holds between the filaments, the maximum amount of such material. Each separate filament tends to scrape off or move some material. The

†The denier designation will be used throughout this paper although the A.S.T.M. Committee D-13[7] has recommended the adoption of the grex system and the Society has accepted it, pending final adoption as standard. Those who wish to convert to grex only need to take the denier number x 1.1111.

spaces between the filaments receive and hold microscopic particles which are removed with the floss.

If the filaments are held together by the usual waxing treatment, the spaces between them are filled by the wax. The floss has the effect, in this regard, of a single solid cord. Separate mechanical action of the many filaments is prevented and the purpose to hold and remove large numbers of microscopic particles between the filaments is defeated, by the presence of the wax.

When an object is forced to pass between the contact points of two teeth in normal direct contact, either the teeth are forced apart sufficiently to permit the object to pass, or the object yields in shape, more or less, and separation of the teeth is required. For instance, a metal wire forced between two contacting teeth, forces them apart as much as the diameter of the wire; heavily waxed or sized nylon floss, under pressure, tends to yield somewhat in thickness, hence less separation of the teeth is produced when it is passed between contacting teeth; small low-twist nylon floss, not waxed, yields readily to pressure, tends to flatten and pass a given point in the close space, only one or a few of the elastic filaments at a time, hence only negligible movement of the teeth is necessary to allow it to pass with ease.

When a piece of the usual form of waxed dental floss is drawn over the surface of a tooth while it is held in the field of a dissecting microscope, it can be seen that a thin film of wax (Fig. 4) is left on the area against which the waxed floss was applied. Another satisfactory experiment is to draw waxed dental floss, back and forth, over the surface of a finger nail. The film of wax left on the nail can be seen with the unaided eye, and the waxy, sticky material can be recognized by feeling it with the finger.

Similarly, when a piece of the same kind of waxed floss is drawn between two contacting teeth and then back out, as in cleaning the teeth, a thin film of wax is left on the contacting surfaces and also on the other surfaces against which it was pressed. This film of wax, although of microscopic thickness, between the contact points of persons who have full sets in normal contact, is sufficient to separate the teeth enough to cause more or less soreness of the sockets for a few hours. The author observed this often when he used to use waxed dental floss in cleaning his own teeth and has confirmed it experimentally several times since. Likewise it has been confirmed by the experience of several volunteer subjects.

It would be difficult to determine whether such temporary microscopic separation of the teeth daily, and the soreness of the sockets caused thereby, is harmful. At any rate it is not desirable. Although it is undoubtedly better than not to use any floss at all, the lessened effectiveness and possible

harmfulness are valid, very definite, objections to waxed floss for personal oral hygiene.

Another objection to waxed dental floss is the film of wax that is left on the surface of the tooth in using it to clean within the gingival crevice. The presence and accumulation of foreign material on the normal smooth

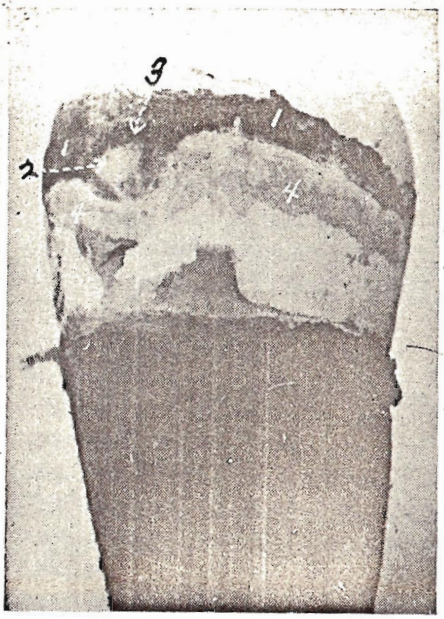

Fig. 5. Extracted tooth stained showing a bacterial disc of film material around the contact area, which is dislodged by passing floss between the teeth

enamel cuticle where the gingival epithelium rests against it initiates gingivitis, the earliest stage of periodontoclasia.[5] Wax from dental floss applied daily to the cuticle in this same area, would have the same kind of foreign body effect, but probably not as great.

Still another objection to waxed floss is the single cord effect, and the relatively unyielding shape, in cleaning the entire depth of the gingival crevice or sulcus (Fig. 1). Low twist floss, without wax or size, adjusts itself more or less to the very narrow space between the gum and tooth, whereas waxed floss does not spread and adjust, to the same extent.

CHOICE OF FILAMENT SIZE

High tenacity nylon yarn is made either "bright" or "semidull." An inert delustrant is added to produce the latter type. Only bright nylon yarn

should be used for dental floss. For trade purposes the manufacturer of nylon designates bright, high tenacity yarn, with no size or oil applied, as "Type 300." This type is the most suitable for dental floss. The relative merits of other types need not be taken up here.

Type 300 nylon is made in different filament sizes ranging from 2 up to 6 denier per filament. The author has devoted much study and experimental work over a considerable period of time in an effort to ascertain the optimum size of filaments for the purpose. The size decided upon is 2 denier per filament. For the information of others who may wish to investigate the question, some of the considerations favoring selection of this size are given here.

If floss made of 1 denier filaments (available in "normal" tenacity only) is drawn against rough surfaces between contacting teeth, although there may be only microscopic roughness, there is considerable breakage of the very fine delicate filaments. This is definitely objectionable. On the other extreme 6 denier filaments are stronger and break less under the same circumstances. However, floss made of this size does not pass with the same ease and smoothness as that made of smaller sizes. It seems that floss made of the larger size filaments cannot mold and adjust to the close space as well as floss made of smaller filaments.

Actually it finally comes down to choosing between the 2 and 3 denier filaments. Micrometric determinations on 100 filaments of each of these two sizes gave an average diameter of .016 mm. for the 2 denier and .020 mm. for the 3. The average for 6 denier filaments is .028 mm. Thus it will be seen that the thickness of the 3 denier filament is only about ¼ greater than the 2, whereas the 6 is nearly twice as thick.

It requires definitely more force to separate teeth enough to pass a 6 denier filament, or a number of overlapping filaments of that size in dental floss, between contacting teeth, than for the 2 denier. The feel of coarseness of the 6 compared to the smooth and easy passage of the 2 denier floss is easily recognized. Two volunteer test subjects, while blindfolded, could differentiate between these sizes almost every time.

In a number of blindfolded practical-use tests the author has been able to correctly differentiate, 8 out of 10 times, between floss of equal total denier made of 2 and of 3 denier filaments. Although the difference is very slight, it is to that extent in favor of the 2 denier size.

In dental floss of a given total denier, the number of filaments is 50 per cent greater, if it is made of 2 denier filament yarn than if made of 3 denier. In use each separate filament may serve to dislodge some small part of the microscopic particles present—bacteria and other. The advantage, in this respect, is definitely in favor of floss made of 2 denier filaments with the larger total number of separate filaments.

An important function of dental floss is to take up and hold for removal, microscopic material, in the spaces between, and on the surface of, the filaments. Since these are considerably more numerous and greater respectively in floss made of 2 denier filaments than that made of 3 denier, there must be some advantage in this regard, of the smaller size. The author has not succeeded in setting a satisfactory experiment to prove the slightly greater effectiveness, in dislodging and removing bacterial material, of 2 denier over 3 denier filament floss. However, this is certainly theoretically true.

A little breakage of filaments occurs when either 2 or 3 denier filament floss is drawn forcibly across rough surfaces, as in cleaning rough surfaces on some teeth. Although the difference is diffcult to demonstrate with certainty, there must be some more breakage in the 2 than in the 3 denier filament floss. However, there is so little breakage in the 2 denier filament floss, when properly used, that this is negligible and unimportant. Whatever slight advantage there is, in this regard, of the 3 denier filament floss, it is far outweighed by the other advantages of the 2 denier filament floss indicated above.

CONSTRUCTION, TWIST

The manufacturers of nylon supply 2 denier filament, Type 300 nylon yarn to manufacturers of floss in the form of 70 denier, 34 filament, Z twist, ½ turn to the inch. The floss manufacturer* must twist together a sufficient number of threads to make the size or total denier of floss desired.

The amount of twist is expressed as the number of turns per inch. The direction of twist is designated as S or Z.†

Some twist is necessary to hold the filaments together during manipulation in cleaning the teeth. Floss with very low twist or with no twist at all passes through close spaces, as between contacting teeth, with the greatest ease. If it is held against the close space and drawn slightly back and forth lengthwise, the somewhat elastic filaments tend to pass a given point singly or in small numbers. On the other hand, hard twisted floss cannot mold or spread out in the same way. Therefore, more force must be applied and the teeth must be spread farther apart for it to pass (usually with a snap).

*The author wishes to thank Richard T. Kropf, Director of Research, Belding Heminway Corticelli, New York, and Stefan L. Grapnel, Research Engineer, Belding Heminway Corticelli, Putnam, Connecticut, for much helpful technical information and for supplies, from Putnam, of many research samples, most of them specially manufactured to conform to specifications which, as our experiments progressed, seemed to be needed.

†A yarn or cord has S twist if, when held in a vertical position, the spirals conform, in direction of slope, to the central portion of the capital letter S, and Z twist if the spirals conform in direction of slope to the central portion of the capital letter Z.

Flosses with 0, 1, 2 or 3 turns to the inch pass between teeth, each with about the same ease. Obviously the filaments of floss with 3 turns to the inch will hold together better, when it is being used and handled, than those of lower twists. Floss with 6 turns to the inch is much harder and more unyielding. In fact one can make out definite difference between 3 turns and 4 turns per inch floss in passing them between contacting teeth. The 4 is just a little harder—and therefore less suited to the purpose than 3.

Soft low twist floss when passed into the proximal gingival crevice, and held or drawn against the tooth there, tends to spread out and flatten (Fig. 3) and to fit without harm into the very deepest part of the space. Round hard twisted floss does not yield so well, therefore, it is less well adapted for use in the gingival crevices. Soft low twist floss dislodges and holds between its filaments, more microscopic bacterial material than hard twisted floss. All evidence together tends to favor a twist of about 3 turns to the inch.

The direction of the twist is of some importance. Most people are right handed. In cleaning the teeth one uses a piece of floss 2 to 3 feet long. One end is wound, with 2 or 3 turns, around the last phalanx of the right index finger, to facilitate holding and manipulating the string. The floss is passed between two teeth, the proximal surfaces down to the bottom of the gingival crevices (Fig. 3) of both of them are cleaned, the floss is withdrawn and then applied to succeeding teeth until all have been cleaned. As the floss is soiled by use, one should move along the string to a clean place from time to time, by taking another turn around the finger now and then. This manipulation tends to twist the string a little to the right. This untwists Z twist floss but holds or slightly increases S twist. While the direction of the twist is not of great importance, the S twist is preferable and should be specified.

Twisted unsized nylon yarn or floss, when it is drawn off from the spool and allowed to go free, untwists, losing almost all of the twist that had been put into it. Therefore, for dental floss, the twist given must be set so it will not untwist in usage. Exposure, for the proper length of time, to live steam is the most satisfactory method. It is especially important that the low twist dental floss here proposed be steamset. Manufacturers should give this matter the necessary attention. Information can be obtained direct from the manufacturers of nylon or from some of their publications.[8]

TOTAL DENIER

The size or total denier of dental floss is important. In making the selection, proper consideration must be given to several different pertinent factors.

The bacterial film pack between two contacting teeth has more or less the form of an irregularly outlined biconcave disc, the thicker portion being at the periphery and the thinner portion at the center (Fig. 5). At the center corresponding to the contact point between the teeth, there is room for only very small amounts of bacterial material. If the margin of the gum has receded from the normal location, then the periphery of the disc is wider (and thicker) on its rootward side.

Fig. 6

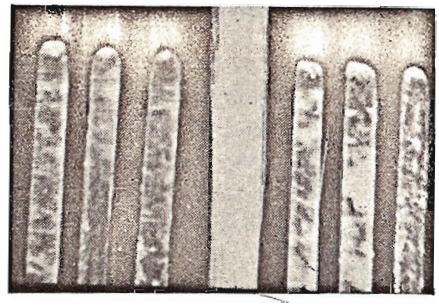

Fig. 7

Fig. 6. Low twist floss of different deniers for comparison. Left to right 1, 1050 denier (waxed); 2, 490 denier; 3, 420 denier; 4, 350 denier; 5, 280 denier; 6, 200 denier; 8, 100 denier

Fig. 7. Piece of 350 denier floss mounted between .007" round end bristles, 3 on other side

The bacterial material between teeth is dislodged and removed by the proper use of the right kind of toothbrush as far as the bristles of the brush can be forced into the space. The optimum diameter of toothbrush bristles has been shown to be .007" (about .177 mm.). The brush therefore cleans between teeth down to where the space is .177 mm. wide. The remainder of the disc of bacterial material around the contact points must be dislodged and removed by the proper use of dental floss.

Soft low twist floss molds and adjusts in shape to fit the space, when it is passed between contacting teeth. Therefore, the diameter of the string should be considerably greater than the .177 mm., to more effectively clean all of the area which cannot be cleaned by the bristles of the toothbrush.

The size floss finally decided upon and advocated here is 350 denier, made by plying and twisting together 5 threads of 70 denier 34 filament yarn. It has been arrived at after long and tedious experiments with many different sizes, ranging from 1050 denier, the size of the usual waxed nylon floss in dental supply and drug stores, down to 100 denier, which is entirely too small for satisfactory effective use (Fig. 6).

The average of 50 separate micrometric determinations of the diameter

of 350 denier floss was .267 mm. This is well above the .177 mm. diameter of the toothbrush bristles (Fig. 7). Although considerable molding and flattening takes place when floss is passed between contacting teeth, it has been found that this 350 denier size effectively dislodges and removes the part of the bacterial film around the contact points which is not removed by the brush.

The size passes between contacting teeth with practically as much ease as any smaller size. The greater bacterial film-dislodging and holding capacity favors it over smaller sizes.

As the size of floss is increased above this 350 denier size it is found to be a little more difficult to pass between contacting teeth. The increased difficulty is so slight, however, with the near larger sizes, that it could be disregarded, if there were any real need for a larger size. But there is not. This 350 denier size, when properly used, is as effective as larger sizes in cleaning the proximal surfaces of teeth around the contact point and toward the gingival margin.

Another important use of dental floss is cleaning the surface of the tooth at the gingival margin and within the gingival crevice, down to the very bottom. Too large a string must be forced, to pass it into the narrow space between the tooth and the gum. Too small a string does not have as much dislodging and holding or removing capacity as larger sizes. What is needed is the largest size that can be nsed in the crevices without harmful forcing.

It has been found that the 350 denier size can be used within the gingival crevice with as much ease and as much effectiveness as smaller sizes. It molds and flattens (Fig. 3) when held against the tooth and passes with the greatest ease to the bottom of the crevice. Larger sizes are a little less satisfactory in this regard, therefore, are not as desirable.

COMMENT

Every person, in any walk of life, who has teeth to save, and everyone who wishes to maintain a reasonable degree of oral cleanliness, must use the right kind of dental floss. Dental floss conforming to the specifications indicated in this paper is the most effective and appropriate for the purpose.

Most people do not now know that it is necessary to use dental floss, or how to use it. They must be taught. Those who are interested in teaching personal oral hygiene, and in promoting dental health and personal oral cleanliness, must give proper consideration to dental floss.

Manufacturers should be able to conform to the specifications here indicated, without difficulty, whenever the demand arises.

SUMMARY

Information has been presented indicating the following optimum characteristics of dental floss for personal oral hygiene:

Material—high tenacity bright nylon yarn ("Type 300"), 2 denier per filament;

Construction—made by twisting together 5 threads of 70 denier, 34 filament yarn;

Twist—3S twist; steamset;

Size—350 total denier.

Manufacturer's technical designation for this floss is: 70-34/5 S 3 Nylon 300, steamset.

1430 Tulane Avenue.

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A WORLD A MAN CAN LIVE IN

The history of man is a history of hunger—hunger for security and for growth. Security, in our complex industrial civilization, means, primarily, the necessities of life—food, shelter, clothing, health care.

Growth means development of the human spirit, the extension of talents, skills and abilities beyond the mere survival efforts of security.

As John F. Wharton has put it: "In any society today . . . there are two conflicting drives in every man and woman, the search for security and the desire to risk it for an opportunity to exercise one's full ingenuity. The resolution of this conflict is one of the basic sociological problems of today."

The twentieth-century dentist cannot escape this problem, for it is not an academic or philosophical one. It confronts him every hour of the day. It tests the fundamental tenets by which he lives. Against an intolerable background of mass dental ill health, he must decide whether his goal is security or growth. His personal philosophy and his professional ethics will determine which role he is to play in life.

It is for him to see that his ethics are as great a resource to the community as are his knowledge and his skill. Those ethics are translated into professional practice through standards of service. If that professional service does not reach all those patients that it might, especially those who need it most, the dentist can well ask himself whether he has not chosen the limited road to self-security, rather than the unrestricted highway to full growth. A man must determine how big, or how small, a world he wants to live in.

The man who goes beyond security becomes a benefactor to the human race. He not only lives a fuller, deeper and richer life himself, but, through his strength and his ingenuity, he helps others to do so. . .

Tic, June 1948