Suggestion for a definition, measuring method and classification system of bristle stiffness of toothbrushes

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Abstract – A definition of bristle stiffness and a measuring method are described and discussed. Sixty-six different brush models, collected worldwide, were measured according to the suggested method. Considerable differences were found between brushes of declared equal stiffness. On the basis of these findings and the method described, a classification is suggested.

Key words: bristle stiffness, toothbrushes.

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An unambiguous and relevant standard for establishing the bristle stiffness of toothbrushes has long been required by manufacturers, consumers/patients and the dental profession.

A number of studies on different aspects of bristle stiffness have been published (6, 11, 13, 14). However, to date there has been no commonly accepted definition of bristle stiffness of toothbrushes, nor any acknowledged means for measuring or declaring such stiffness. A number of studies have been carried out investigating the relationship between the bristle stiffness and cleaning ability/possible trauma (1–5, 7–10, 12, 15, 16). Definite conclusions as to the significance of stiffness have yet to be established.

Such research has also been complicated by lack of an internationally accepted definition of bristle stiffness. A stiffness classification seems to have been in demand for a long time by the manufacturers, the dental profession and the patients/consumers.

The purpose of the present study is to suggest a definition of bristle stiffness of toothbrushes, a method for measuring the stiffness, and a classification system which is applicable and easy to use for all parties concerned.

Material and methods

This study is based upon the following definition of toothbrush stiffness: The reaction force per square unit caused by deflecting the toothbrush bristles down to two-thirds of their original length.

The stiffness (ST) is expressed in grams as follows:

$$ST = \frac{F_1 + F_2}{2A}$$

ST = stiffness.
F_1 = force necessary for deflection down to two-thirds of original length at 20°C dry state (50 ± 5% humidity).
F_2 = force at 12°C wet state.
A = toothbrush head area limited by the circumference of the projection of all tufts.

One deflection measurement is made at 20°C at a humidity of 50 ± 5%. (Brushes are kept for at least 2 h under these conditions prior to measuring.) The second measurement is made after 90-s submersion in water of 12°C (normal pipe water temperature). When the brush has a profile cutting or is V-shaped, the height is decided as the median of the bristle lengths.

Jordan's measuring apparatus for the stiffness factor of toothbrushes (Fig. 1) consists of two units: a measuring unit and an indication unit. The measuring unit consists of a lengths measurer and a pressure transducer. A time relay controls the weight readings on the weight indicator and they are shown in digits on the indicator for 10 s. Measurements with Jordan's apparatus have shown that the bristles yield and become softer after relatively few seconds. The stiffness is therefore measured immediately after it has been inserted on the PTFE surface.

The apparatus works in the following way: The toothbrush is moved axially over a PTFE-covered plane surface. A PTFE-covered surface is used in order to minimize the lateral friction. The bristle length for a straight-cut brush profile is automatically shown in digits. Two-thirds of the bristle length is then calculated and the apparatus is readjusted to this height. The toothbrush is again moved over the plane surface and the total force is shown on the indicator. The force is recorded in grams. The area (mm^2) which is limited by the circumference of the projection of all the tufts is calculated, and the force is divided by this area (Fig. 2).

In order to verify this method for measuring toothbrush stiffness and as a basis for suggesting a classification of bristle stiffness, 330 brushes of 66 different models collected worldwide were measured.

Five brushes of each model were considered

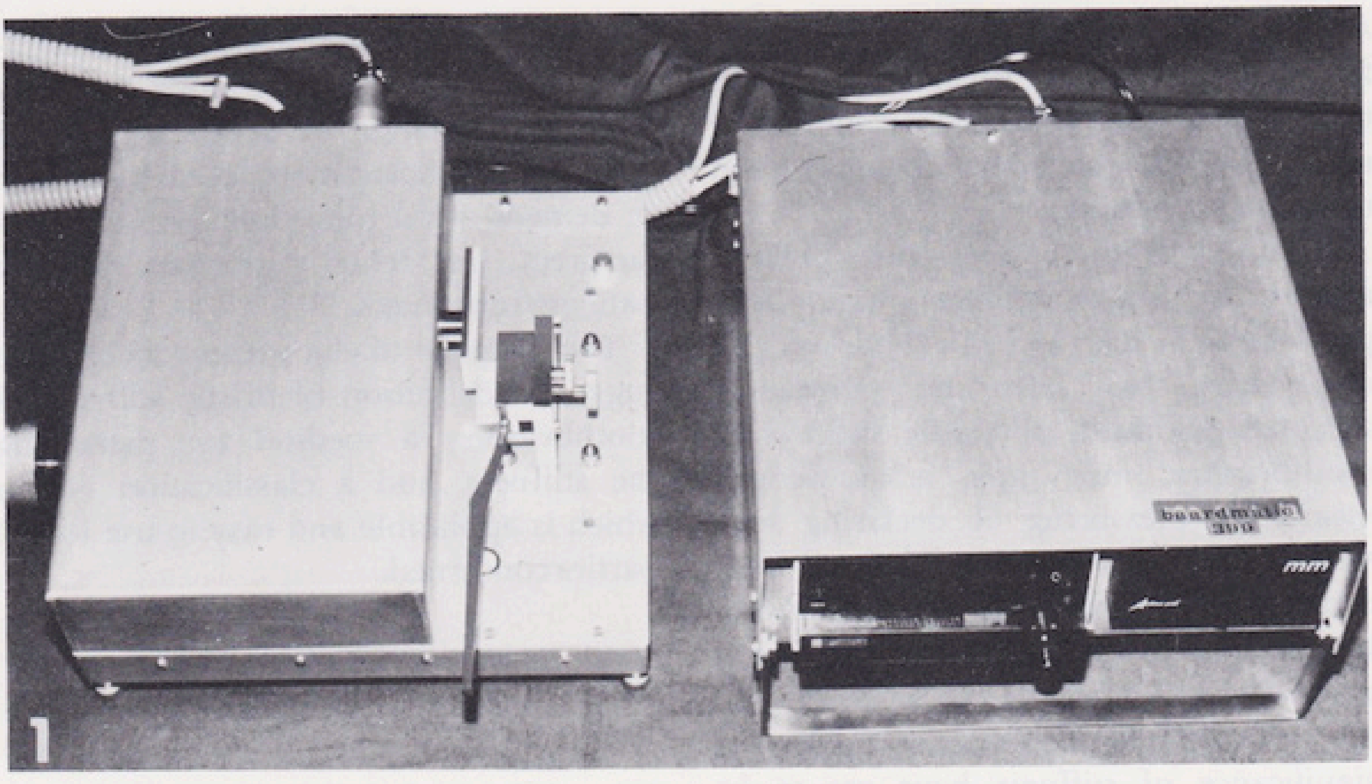

Fig. 1. Baardmatic 399.

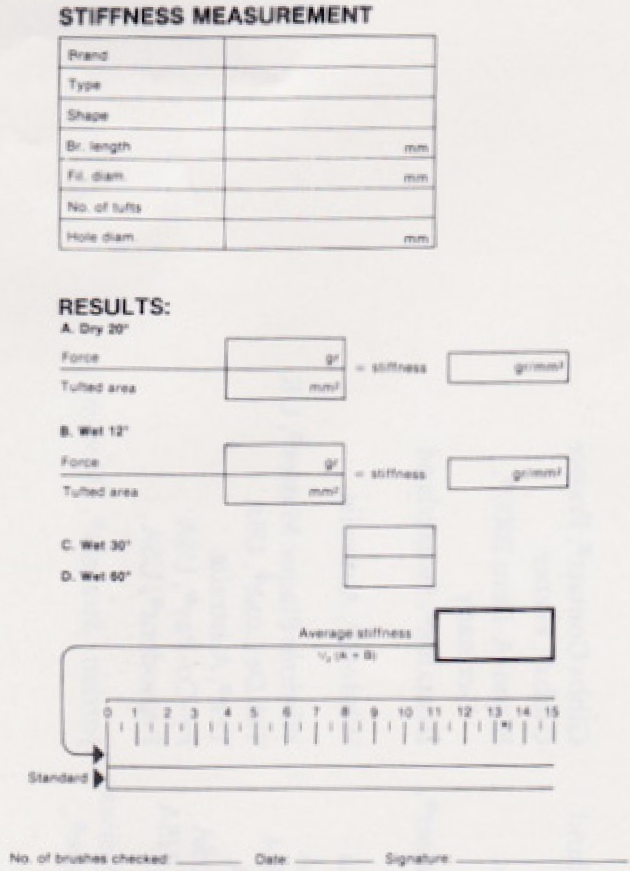

Fig. 2. Registration form.

necessary to reduce the influence of possible manufacturing variations.

The brushes collected and used in this study are listed in Table 1.

Results

Of 94 brush models collected, only 66 had a special declaration indicating their stiffness. The brushes without special stiffness declarations were eliminated from this study. The stiffness grades found were: Extra Hard, Hard, Medium, Soft, Extra Soft. The remaining 28 brushes had, in addition to brand names, non-descriptive declarations like: Child, Junior, Double Action, Short-Head, Anti-Plaque, etc.

Generally, the tendency was for the stiffness declarations given by the manufacturers to be in good agreement with the measurements made. These measurements showed, however, great variations in stiffness from model to model within the five different groups. Considerable overlaps were found between the five declaration groups. One model declared "extra soft" was measured stiffer than the median of the "soft" brushes. Three models in the "soft" group were softer than the median of the "extra soft". One was stiffer than the median in the "medium" group, close to the median in

BRUSHES		VALUES MEASURED		
DECLARED AS	NO.	LOWEST	HIGHEST	MEDIAN
EX. HARD	3	7.3	12.6	9.4
HARD	15	5.0	11.1	8.4
MEDIUM	17	3.8	9.2	5.9
SOFT	26	3.1	7.9	4.6
EX. SOFT	5	2.5	4.8	3.7
	66			

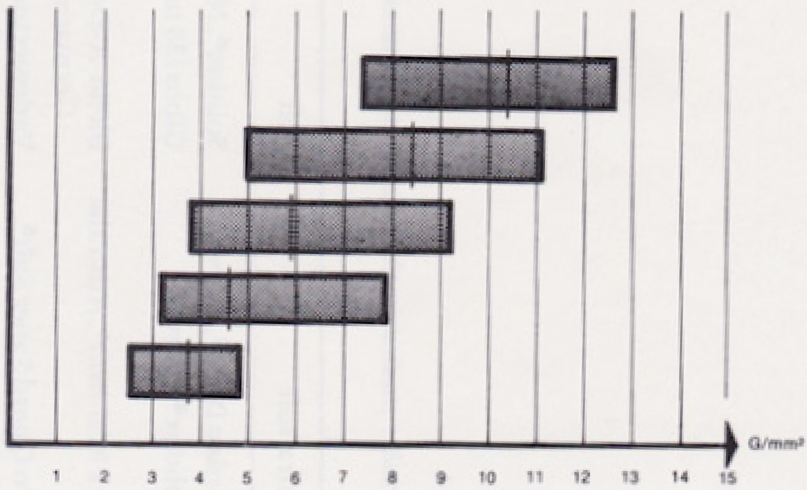

Fig. 3. Stiffness measurements of 66 toothbrush models.

Table 1

Brushes studied in the present investigation. In addition, 24 models were collected, but excluded from the measurement because they lacked information about stiffness

Extra soft	Soft	Medium	Hard	Extra hard
Jordan Delta®, Norway	Solidox®, Norway	Boots, V-shape®, UK	Boots, V-shape®, UK	Smokers, Boots®, UK
Solidox®, Norway	Gibbs (38 tufts)®, France	Blend-A-Dent 2000®, Germany	Pro 300 H®, USA	Tek Extra Hard®, Australia
Tek Multisoft®, Australia	Blend-A-Dent 2000®, Germany	Dentalux®, Switzerland	Gibbs Contact®, France	
			Gibbs®, France	
Pro Guard Super Soft®, USA	Vademecum®, Sweden	Wisdom®, Australia	Blend-A-Dent 2000®, Germany	
	Wisdom®, Australia			
Jordan Super Soft®, Norway	Wisdom Soft®, UK	Wisdom Plaque Master®, UK	Dentalux®, Switzerland	
	Te-Pe Mjuk®, Sweden	Tek Med®, Australia	Wisdom®, Australia	
	Tek De Luxe®, USA	Pycopay Med®, USA	Wisdom Plaque Master®, UK	
	Tek®, Australia	Pro Guard 425®, USA	Tek De Luxe®, USA	
	Pro 325, Soft®, USA	Pro 325 Med®, USA	Tek®, Australia	
	Pycopay Softex®, USA	Pepsodent Med®, USA	Py-Co-Pay®, USA	
		Lactona Medium®, USA	Pepsodent®, USA	
	Pro 325s®, USA			
	Pro Guard 420®, USA	Jordan Popular®, Norway	Jordan Straight®, Norway	
	Pepsodent Soft®, USA	Jordan Med. V-shape®, Norway		

Oral B 60 Soft®, USA	Jordan Med. Straight®, Norway	Jordan V-shape®, Norway
Oral B 40 Soft®, USA	Fam. Fresh Straight®, Sweden	Colgate®, USA
Oral B 35 Soft®, USA		
Oral B 30 Soft®, USA	Fam. Fresh V-shape®,	
Nada, Soft®, Australia	Sweden	
Lactona M391®, USA	Colgate®, USA	
Jordan Shorthead®, Norway		
Jordan Soft V-shape®, Norway		
Jordan Soft, Straight®, Norway		
Gibbs (44 tufts) Souple®, France		
Colgate®, USA		
Tek, Soft®, USA		

the "hard" group. In the "medium" group, two models were found softer than the median of the "soft" group and one model stiffer than the median in the "hard" group. One model in the "hard" group was below the median in the "medium" group, while five were above the median of the "extra hard" group. In the "extra hard" group, two of the three models measured were softer than the median of the "hard" group (Fig. 3).

The findings confirmed that, in the absence of an unambiguous and relevant standard, the manufacturers' declarations are often misleading or non-descriptive with regard to stiffness.

Discussion

Development of a simple method for measuring stiffness of toothbrushes is considered relevant as it has been in demand for a long time.

A toothbrush should be categorized in degrees of stiffness and not of hardness as it must be understood as a deflection force and not as hardness of a material, according to, for instance, the Shore or Brinell scale.

The length and diameter of the filaments have been considered decisive for the stiffness (12, 13). The stiffness, however, is a function of many factors, such as bristle material, the diameter and length of the bristles, number of filaments per tuft, number of tufts, positioning of the tufts, bristle design (profile), humidity and temperature when used in the mouth. Measuring methods which take many of these factors into consideration have been described (11). However, these methods do not measure the whole brush, but rather tufts of filaments, and they do not include all the decisive factors listed above, the total of which gives the stiffness of the toothbrush. Therefore the stiffness can be expressed as the pressure necessary for or resistance against deflection of the active part of the bristle plane.

In toothbrushes the filaments support each other to varying degrees from brush to brush, depending on the tufts' positioning, length, density and mutual friction. One single filament is insufficient to create the feeling of stiffness.

The total brush head rather than single filaments or single tufts must be considered. The conclusion cannot, however, be drawn that by measuring the whole brush head's resistance to deflection a relevant concept of the stiffness can be

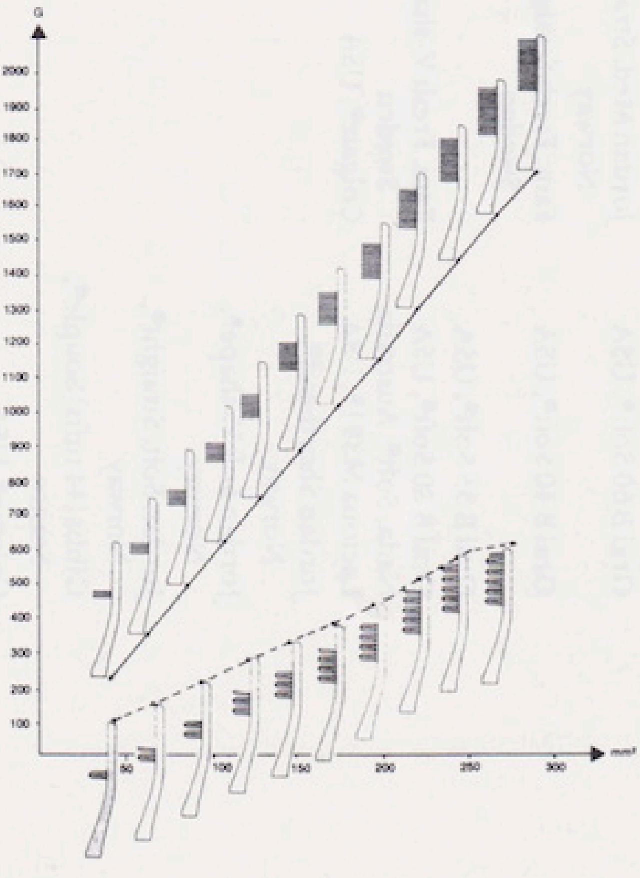

Fig. 4. Deflection force related to number of tufts. Measured on two different brushes, Hard multitufted and Soft V-tufted.

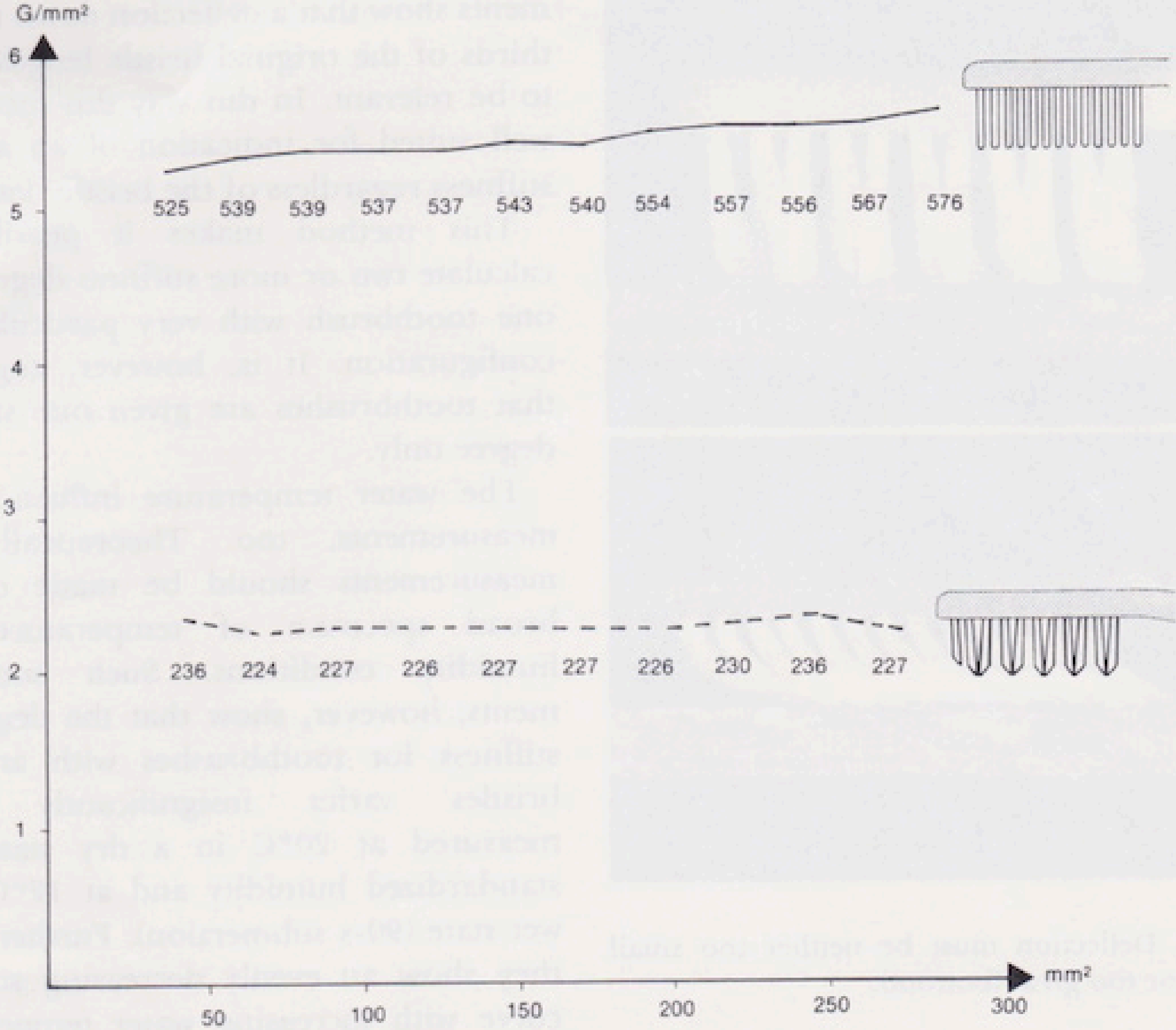

Fig. 5. Deflection pressure (stiffness) is not affected by the size of the brush head.

obtained. Experiments show that the total necessary deflection force increases proportionally with the size of the brush head (Fig. 4). This means that brushes with especially large heads will be measured as the stiffest. To prevent the size of the head deciding the stiffness, the measured deflection force must always be related to a fixed area, i.e. deflection force to bristle area (Fig. 5). This area is defined as the projection of all the tufts of bristles on the toothbrush head expressed in mm². The contact area will, when the bristles are deflected, be somewhat larger than when undeflected. But there is an approximate proportion so that the area measurements can be made before deflection. Accordingly, the size of the head will not influence the stiffness.

The deflection force is measured perpendicular and not lateral to the area of contact. (It is the perpendicular force component, during brushing, which mainly dictates the feeling of stiffness; the lateral "friction" is minimal.) The issue is therefore to measure the force necessary to deflect the brush head down to a lower level than its original height. To decide the brush stiffness will therefore mean to measure the force necessary to deflect the bristle plane from its original length to a defined shorter level. Reducing the length by a fixed distance will not compensate for possible differences in original filament

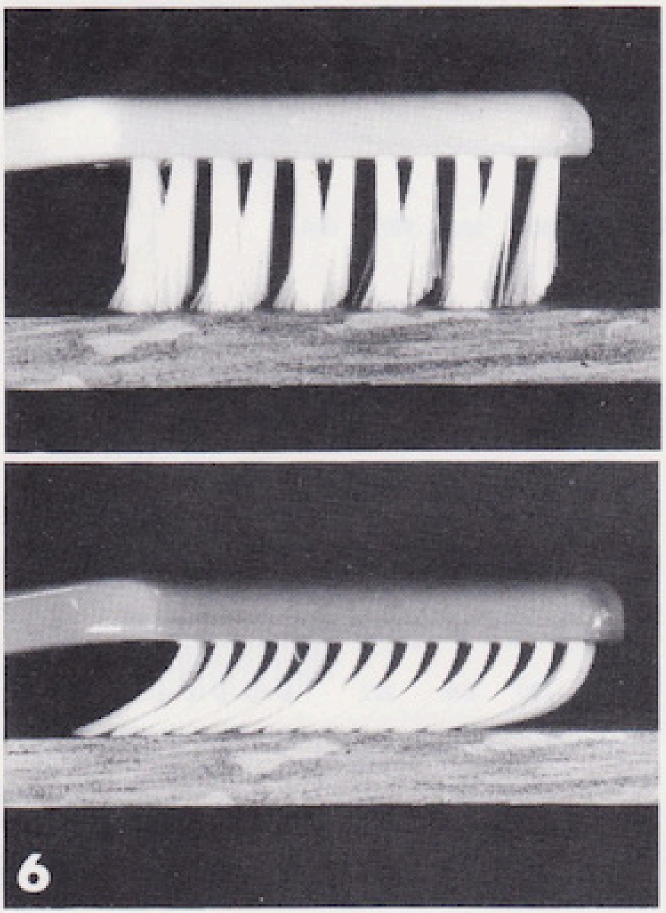

Fig. 6. Deflection must be neither too small (top) nor too great (bottom).

lengths (profile cutting). It would require more force to deflect short bristles than long bristles a fixed distance of for instance 6 mm. Consequently it is natural to decide the deflection in percent of the original length. The measuring of straight bristles poses no problems. For unevenly cut profiles, however, the median bristle length must be calculated.

A deflection which is too little will not reflect the influence of the shorter filaments in special cutting profiles. On the other hand too heavy a deflection will lead to increased contact with the sides of the bristles instead of their tips. It is especially the tips or ends of the filaments that create the feeling of stiffness. A further increased deflection may result in a packing of the filaments (Fig. 6). Experiments show that a deflection down to two-thirds of the original bristle length seems to be relevant. In this way this method is well suited for indication of an average stiffness regardless of the bristle design.

This method makes it possible to calculate two or more stiffness degrees for one toothbrush with very particular tuft configuration. It is, however, suggested that toothbrushes are given one stiffness degree only.

The water temperature influences the measurements, too. Theoretically the measurements should be made over a broad spectrum of temperature and humidity conditions. Such measurements, however, show that the degree of stiffness for toothbrushes with artificial bristles varies insignificantly when measured at 20°C in a dry state and standardized humidity and at 12°C in a wet state (90-s submersion). Furthermore, they show an evenly decreasing stiffness curve with increasing water temperature (Fig. 7). The relative differences between most of the commercially available toothbrushes are approximately the same whether measured under high or low temperature or in a wet or a dry state. Ninety-second submersion was chosen because this reflects a normal brushing situation.

Natural bristle brushes are far more difficult to characterize. Due to a high water absorption there is a significant difference in stiffness between dry brushes and wet brushes after 90-s submersion (Fig. 8). This standard defines the degree of stiffness as a calculated average of two measurements, i.e. in a dry state at 20°C room temperature (50 ± 5%) and in a wet state after 90-s submersion in water at 12°C. This applies to the toothbrushes with artificial filaments as well as to toothbrushes with natural bristles. By such a definition natural bristle brushes can be

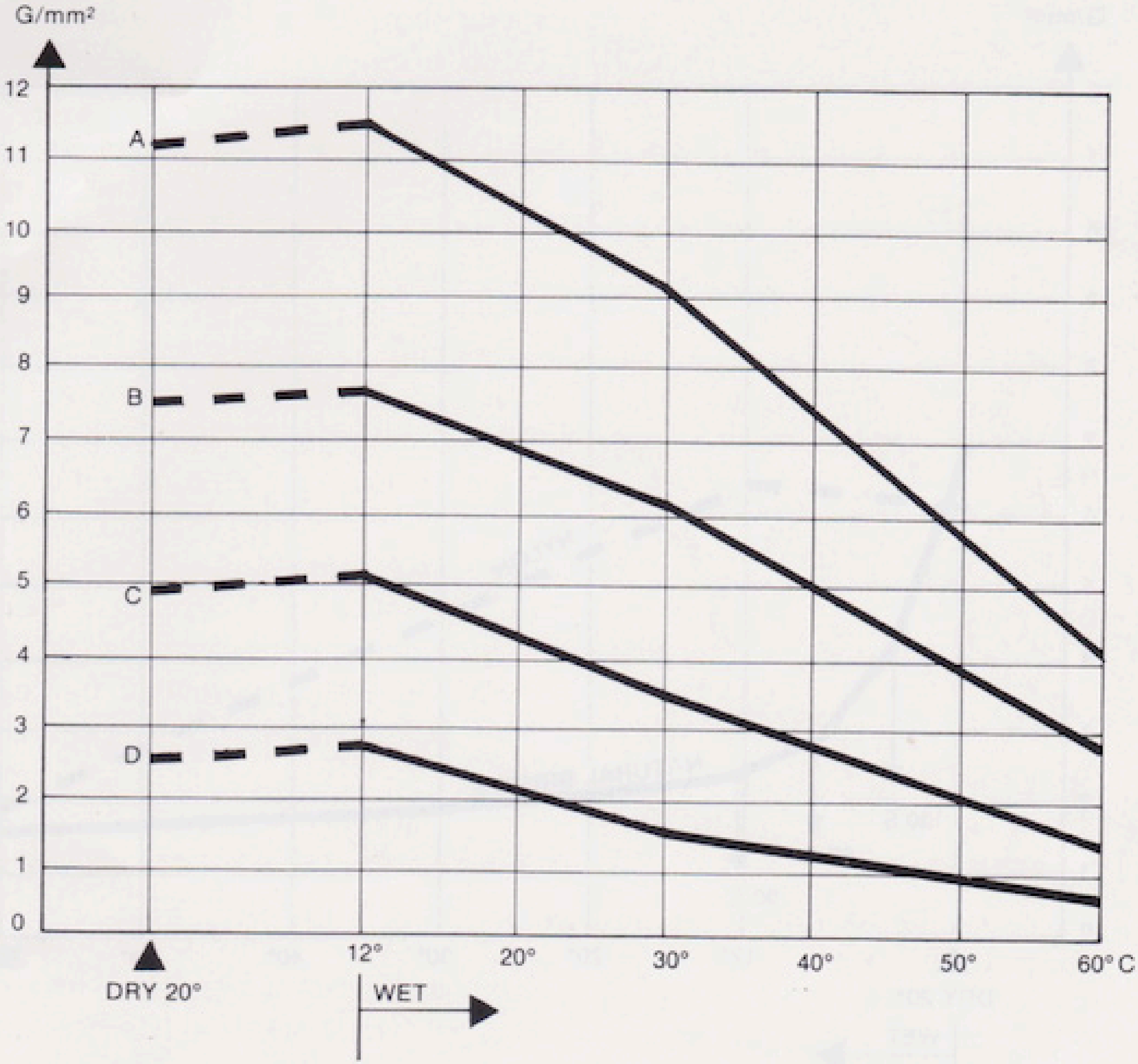

Fig. 7. Bristle behavior in four different brushes (Extra hard, Hard, Medium and Soft). Dry state and wet state with increasing water temperature.

given a classification which is comparable to artificial bristle brushes.

The device shows a high degree of precision. All measurements are repeatable, both for bristle length and for deflection force. Even diminutive variations in bristle configurations are easily discovered.

The measuring of 66 different toothbrush models from different parts of the world was partly done to verify the method. Primarily, however, the measurements were done to establish a basis for suggesting a relevant classification of stiffnesses. In order to maintain the established and familiar stiffness classes, a classification based upon these five grades in use is suggested. In order to obtain maximum correspondence with existing declarations – and at the same time a natural and easily understandable system, different scales have been compared with current classifications (Fig. 9).

It is obvious, due to a high degree of overlapping in current declaration values, that a certain amount of today's declarations will fall outside a new classification standard, no matter where the dividing

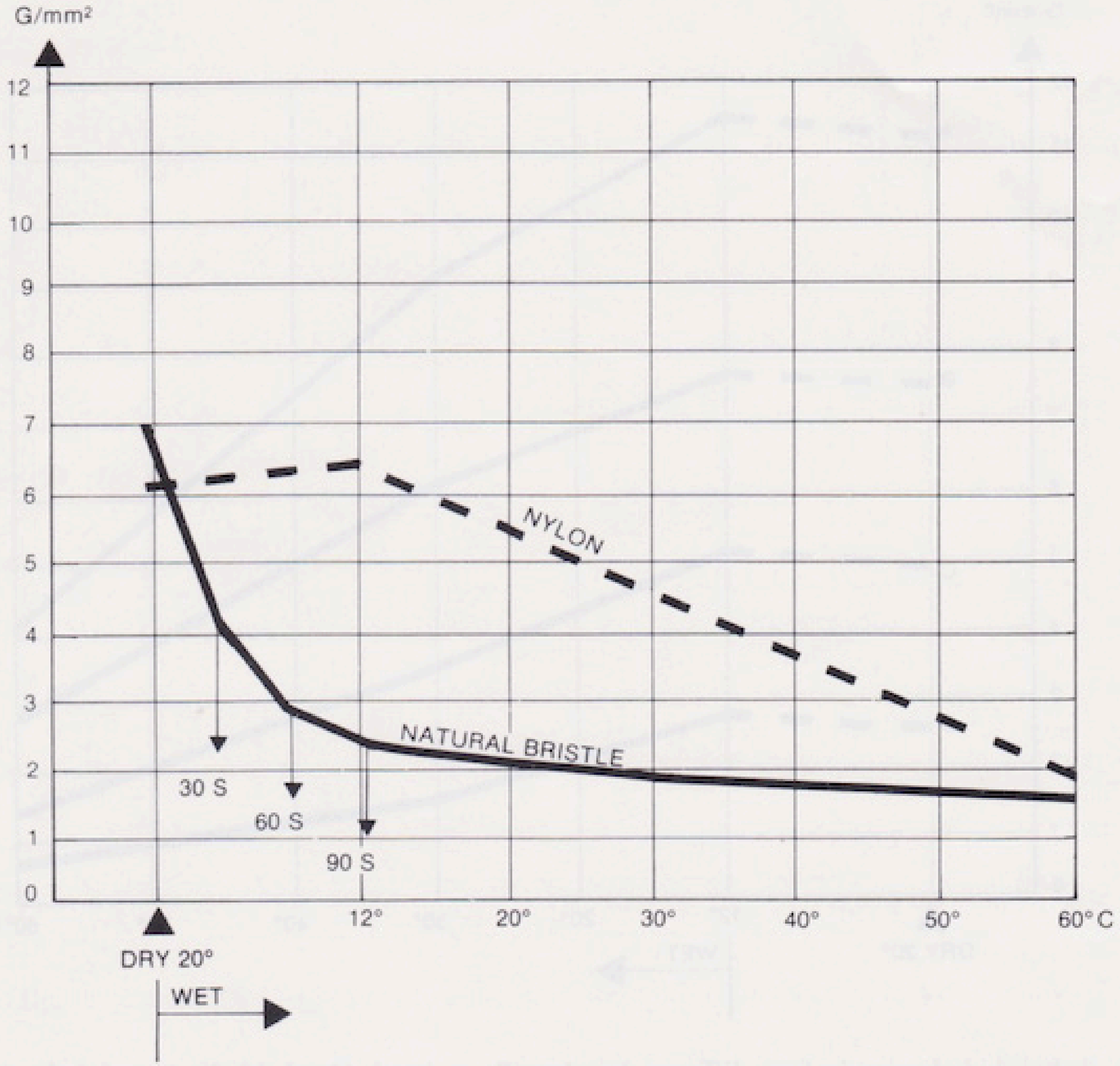

Fig. 8. Change of stiffness of natural bristle brushes from dry to wet state and with increasing temperature.

lines are drawn. The problem is to minimize the number of models getting a declaration differing from their present one.

The suggested declaration scale corresponds well with the existing declarations made by the manufacturers:

Extra soft = brushes measured 2.99 g/mm² or less; Soft = brushes measured from 3.00 to 5.49 g/mm²; Medium = brushes measured from 5.50 to 7.99 g/mm²; Stiff (hard) = brushes measured from 8.00 to 10.49 g/mm²; Extra stiff (Extra hard) = brushes measured 10.50 g/mm² or above.

Of the 66 models, 42 (64%) were declared according to the measurements, while 15 (23%) were declared too soft, and nine (13%) were declared too hard.

All measurements should be performed according to the method and with the equipment described. All brushes, independent of brand names and other descriptions, should then be given a classification according to this standard. This applies also to children's brushes, which today usually are unclassified.

Tandbørstens evne til å fjaerne plaque. II. Betydningen av børstehovedets størrelse og fiberbundt-placeringen. *Tandlaegebladet* 1971: **75**: 189–196.
11. MacFarlane, D. W.: The dynamic stiffness of toothbrushes. *J. Periodontal Res.* 1971: **6**: 218–226.
12. Pucket, J. B.: Bristles in hand manipulated toothbrushes. *J. Periodontol.* 1970: **3**: 121–134.
13. Robertson, N. A. E. & Wade, A. B.: Effect of filament diameter and density in toothbrushes. *J. Periodontal Res.* 1972: **7**: 346–350.
14. Sangnes, G.: *Effectiveness and adverse effects of toothbrushing procedures.* Thesis. Universitetsforlaget, Oslo 1975.
15. Sauerwein, E.: Traktat über die Zahnbürste. *Dtsch. Zahnaerztl. Z.* 1970: **3**: 121–134.
16. Scully, C. M. & Wade, A. B.: The relative plaqueremoving effect of brushes of different length and texture. *Dent. Pract.* 1970: **20**: 244–248.

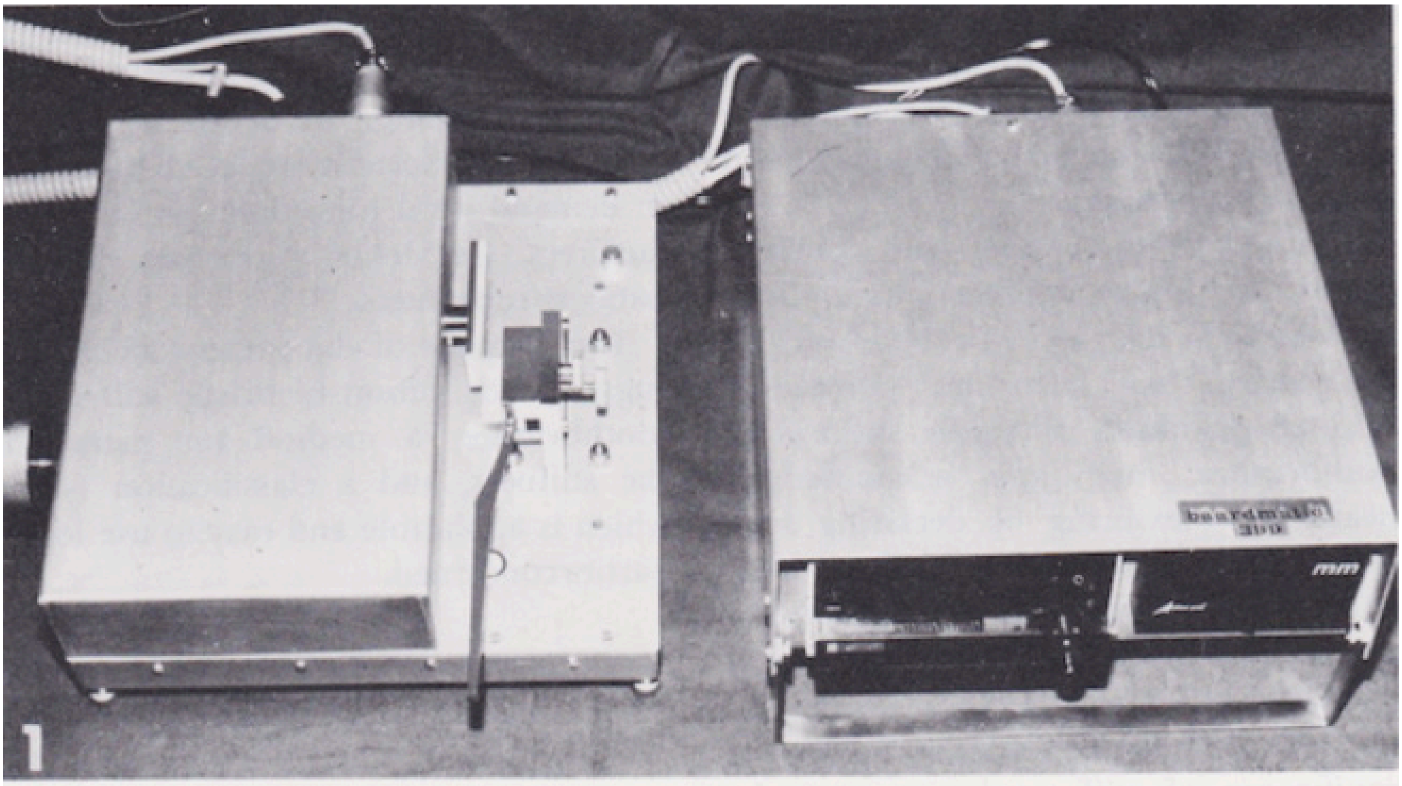

Fig. 1. Baardmatic 399.