Evaluation Method of Hairstyling Materials and its Application to Cosmetic Preparations

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Summary

Instead of sensory evaluation, we designed an evaluation method of the setting function of hairstyling products, based on an original theory focusing on changes in bending stress observed when a load with continuous bending is applied to human hair. Specifically, we developed a device to measure bending stress to quickly and objectively evaluate the condition of human hair, particularly its dynamic properties such as the setting function, following the application of hairstyling products. This device generates a load with continuous bending while applying a pendulum motion to a hair tress, one end of which is anchored.

The setting function and holding power of resins of various molecular weight and ionic properties were evaluated using this device. The results demonstrated a close correlation with those obtained by experts' sensory evaluation. The evaluation results of bending stress and holding rate confirmed that the combined use of two different resins could improve the function of setting preparations.

Evaluation using this device was able to substitute for sensory evaluation, and offers quick objective evaluation and detection of changes in the holding power of hairstyling products over time. We conclude that evaluation using this device is a promising new method.

Introduction

Numerous types of hairstyling products with various setting functions and finishing touches are being designed and developed to incorporate consumer preferences and latest trends. Consumers require hairstyling products that meet their demands to have their hair done as they wish and keep the hairstyle for a long time.

In order to develop hairstyling products with properties that meet consumers' demands, a method of objectively and quickly evaluating the setting function of styling cosmetics needs to be developed, as a substitute for sensory evaluation, which is currently used for evaluation of the setting function of hairstyling products. However, sensory evaluation has problems in objectivity because it largely relies on the evaluator's technical skill, and the evaluation criteria often vary depending on the evaluator.

The currently used evaluation methods, [1], [2], [3], such as the Curl Retention Method, provide evaluation of only one aspect of the setting function of hairstyling products. Therefore, the correlation of their results with hairdressing function has not yet been fully examined by actual use of hairstyling products.

Furthermore, current evaluation methods do not consider changes in the setting function over time (hold of a hairstyle) and changes produced by dynamic factors such as exercise or touching the hair, which might occur when hairstyling products are applied to the hair. Therefore, the current evaluation methods have not produced satisfactory results from the standpoint of actual usage conditions.

We designed a promising new evaluation method by which changes in the holding power of hairstyling products over time can be detected. This new evaluation substitutes for sensory evaluation, and offers objective and quick assessment of the setting function of hairstyling products and detection of changes in the holding power over time. This evaluation method was established based on an original theory focusing on changes in bending stress observed when a load with continuous bending is applied to human hair, and its applicability in the product development process has been examined.

Experimental

Design of evaluation model

The setting function and holding power of hairstyling products can be evaluated by examining the deformation of anchored hair caused by an external dynamic load. We prepared four models to examine how the state of a "beam" is deformed by "bending". [4]

A hair tress was anchored in the following two models: In the "simple beam model", both ends of a hair tress were anchored, and in the "cantilever model", only one end of a hair tress was anchored (Figs. 1 and 2). Generally, bending displacement can be provided by applying a load evenly on a beam - "distributed load type", or applying a load on one point on a beam - "concentrated load type" (Figs. 3 and 4).

Considering that the hair is anchored at one end under actual conditions and high repeatability can be achieved when a shearing force is applied with a concentrated load, we used a "cantilever model" in which a concentrated bending load was applied in this study.

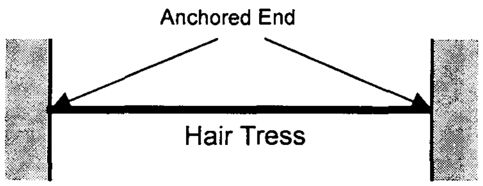

Fig.1 Simple beam model

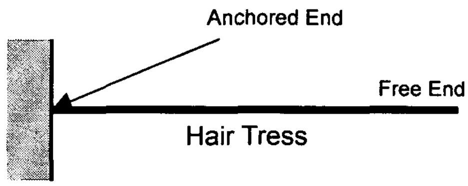

Fig.2 Cantilever model

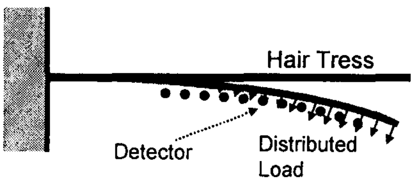

Fig.3 Distributed load type

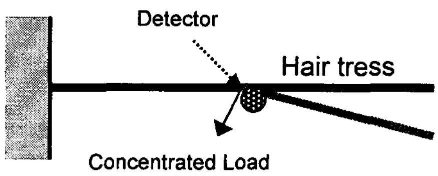

Fig.4 Concentrated load type

Design of device for bending test

A diagrammatic illustration of the test device is shown in Fig. 5. [4] One end of a hair tress was fixed, and pendulum motion was applied to the other end. To evaluate the setting function of hairstyling products, a sensor was placed between the anchored end and the movable end, and the concentrated load generated by continuous bending of the hair tress was measured. By assuming that a load with continuous bending accelerates changes in the setting function, the holding power of hairstyling products was evaluated using attenuation of the load displayed by the sensor.

Figure 6 shows the device we used for evaluation (device for bending test).

1) Movable part: A hair tress was hung vertically and its upper end was anchored. The other end (lower end) of the hair tress was swayed using a pulse motor, and bending stress was applied to a certain point of the hair tress. The amplitude, speed, and number of repetitions of the pendulum motion were able to be set freely.

2) Detection part: The concentrated load at the bending point was detected with a strain gauge.

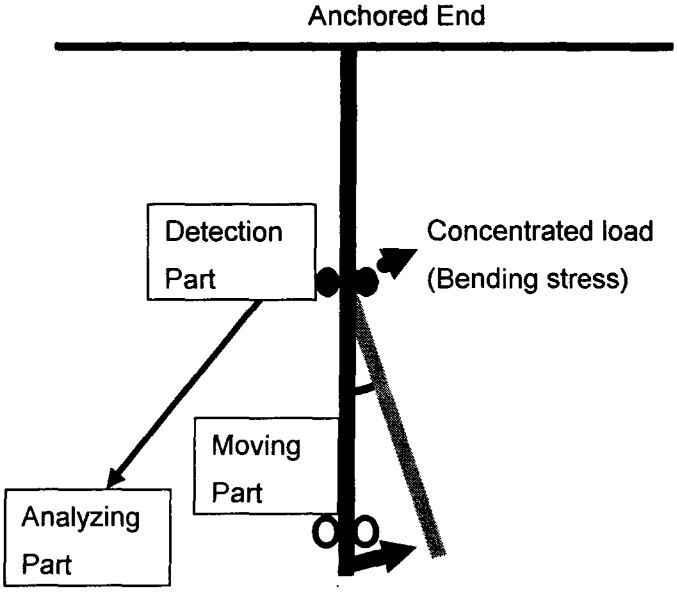

Fig.5 Diagram of the device of bending test

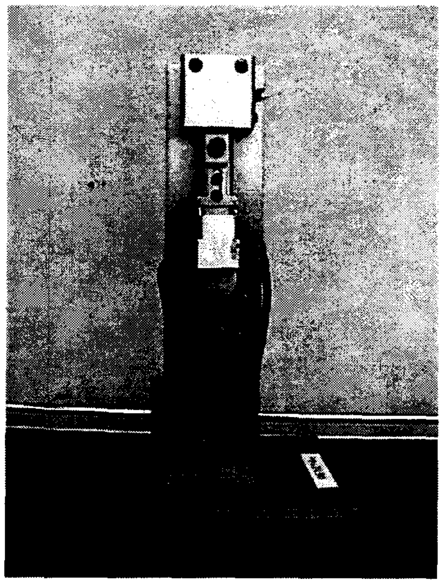

Fig.6 Photograph of the device of bending test

Preparations of setting resin solution

We selected setting resins generally used for preparations of hard setting hairstyling products as samples for evaluation. We prepared a 5% solution by diluting the setting materials with alcohol and purified water unless otherwise specified.

Measurement method

Hair of Asians selected by experts was cut into 6 cm lengths (weight: 10±1 mg) for the bending test. A hair tress was made using 10 selected hairs. Then, the hair tress was soaked in each solution of setting preparation for a certain period of time and dried in a thermo-hygrostat (25±1℃, 55±1%) before use.
The measurement conditions were as follows: amplitude; ±30 degrees, speed; 90 degrees/second, and number of repetitions; 50. In one set of measurements, the load applied when the hair tress was bent at +30 degrees was measured 50 times. Three sets of measurements were conducted. The median was taken as a measure of central tendency. The mean of the initial five bending stress measurements was taken as the initial bending stress, and the mean of the last five bending stress measurements was taken as the temporal bending stress.

Sensory evaluation

In the sensory evaluation, three expert evaluators ranked the setting preparations with respect to the setting function and holding power of the setting preparations using a paired comparison method.

Results and discussion

Verification of device for bending test

We examined whether evaluation of the setting function and holding power was possible with the device for bending test we designed for this study to detect changes in the beam caused by bending of a hair following application of setting preparations. We used a polyvinylpyrrolidone/vinyl acetate copolymer (VP/VA copolymer), which has brittleness and setting function, and a copolymer of vinylpyrrolidone and N, N-dimethylaminoethyl methacrylate (polyquaternium-11), which has setting function and holding power, and conducted measurement with the bending test device.

Figure 7 shows the results obtained when a VP/VA copolymer was used as a setting preparation. In the graph, bending stress is shown on the vertical axis and time after bending is shown on the horizontal axis. This graph presents a waveform because the bending stress is expressed as a positive value when the hair tress swings to one side and as a negative value when the hair tress swings to the opposite side. In Fig. 7, when a VP/VA copolymer was used as the setting preparation, the bending stress became smaller after the initial bending stress was applied, which shows that following application of setting preparations the hair was deformed by a shearing force and its reaction force decreased. This result indicates that the VP/VA copolymer is a brittle resin with low flexibility, although it has setting function initially.

Figure 8 shows the results obtained when polyquaternium-11 was used as a setting preparation. There was no difference between the initial and temporal bending stress. Following application of polyquaternium-11, a hair tress showed no deformity by a shearing force and its reaction force was maintained. This result indicates that polyquaternium-11 is a flexible resin with high holding power.

These results indicate that evaluation of the setting function and holding power of setting preparations was possible with the bending test device we designed for this study.

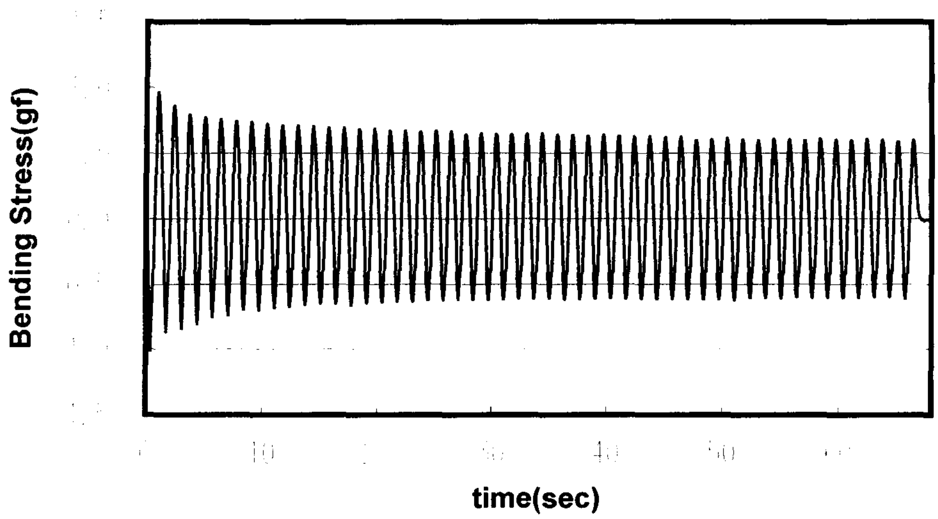

Fig.7 Analysis of detected data obtained when VP/VA copolymer was used.

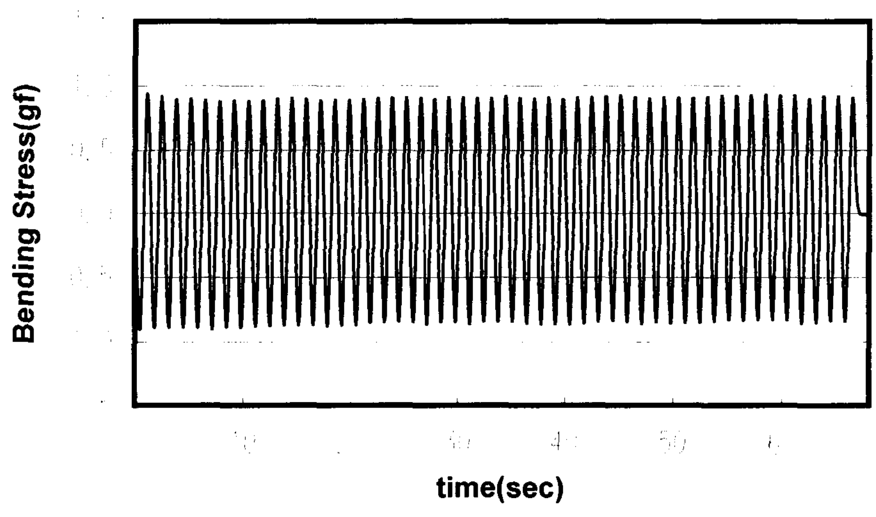

Fig.8 Analysis of detected data obtained when polyquaternium-11 was used.

Dynamic properties of setting preparations

We selected twelve types of resins with various molecular weight, ionic properties and composition, as shown in Table 1.

Figure 9 shows the results of measurement of the initial and temporal bending stress with various setting preparations obtained with the bending test device designed for this study. The results show that the setting function and holding power of resins of various molecular weight and ionic properties were able to be predicted from the initial and temporal bending stress.

Table 1 List of setting resin

Resin	Symbol	Ionic Property
PVP(1)	a	Nonion
PVP(2)	b	Nonion
VP/VA Copolymer(1)	c	Nonion
VP/VA Copolymer(2)	d	Nonion
VP/VA Copolymer(3)	e	Nonion
Polyquaternium-11(1)	f	Cation
Polyquaternium-11(2)	g	Cation
Polyquaternium-11(3)	h	Cation
Polyquaternium-11(4)	i	Cation
PVM/MA Copolymer	J	Anion
Octylacrylamide/Acrylates/ bu ylaminoethyl Methacrylate Copolymer	k	Amphoteric
Methacryroyl Ethyl Betaine/aclyrate Copolymer	l	Amphoteric

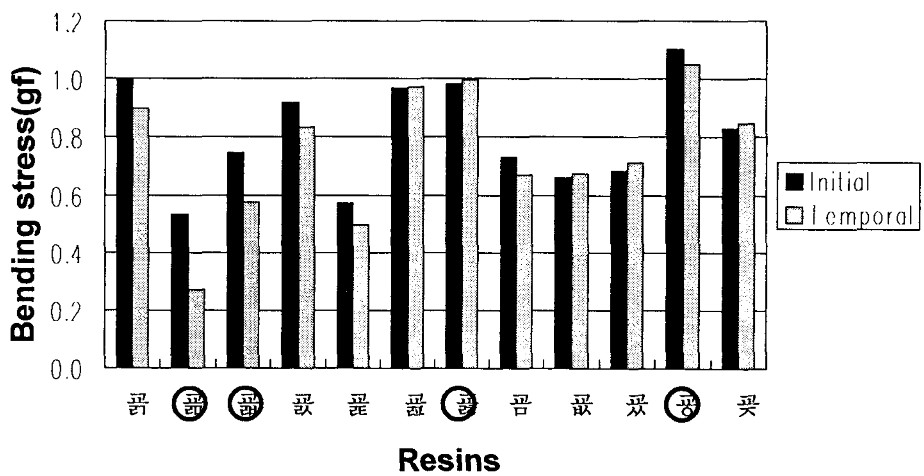

Fig.9 Bending stress of resins evaluated using the device of bending test

Correlation of results obtained by evaluation using device for bending test and those obtained by sensory evaluation

Selecting four types of resins from the above-mentioned twelve resins (circled), experts conducted sensory evaluation to study its correspondence with the results obtained with the bending test device. In the sensory evaluation, the setting function and holding power were ranked using a paired comparison method. Table 2 shows the results. In the ranking of setting function, samples g and k, which had high setting function, changed places between evaluation using the bending test device and sensory evaluation. In the ranking of holding power, although evaluation by alternative methods has so far been impossible, the results obtained by evaluation using the bending test device correlated highly with those obtained by sensory evaluation.

The above results show that evaluation with the bending test device produced almost the same results as sensory evaluation in terms of setting function. In terms of the holding power of setting preparations, which cannot be evaluated with current evaluation methods, the results obtained with this device showed an extremely high correlation with those obtained by sensory evaluation.

Table 2 Correlation of results of sensory evaluation and results using the device of bending test

Evaluation Method	**Setting Function**	**Setting Holding Function**
Device for Bending Test	**k□g ≻c ≻b**	**g ≻k ≻c ≻b**
Sensory Evaluation	**g ≻k ≻c ≻b**	**g ≻k ≻c ≻b**

Evaluation of effects of combined use of setting materials

To confirm the applicability of evaluation with this device, we studied whether the effects of combined use of setting materials used as hairstyling products could be examined with this device.

Regarding combinations of setting materials, VP/VA copolymers and polyquaternium-11 at various concentrations were used in combination. VP/VA copolymers at three concentrations of 2.5, 5.0 and 7.5%, and polyquaternium-11 at concentrations of 0, 0.5, 1.0 and 1.5% were tested.

Figure 10 shows the initial bending stress when a VP/VA copolymer and polyquaternium-11 were used in combination. Figure 10 indicates that bending stress was not increased by simply increasing the amount of copolymers. Figure 11 shows the correlation between polyquaternium-11 and bending stress when the concentration of VP/VA copolymer was 5%.

Not only the initial bending stress but especially temporal bending stress became higher when setting materials were used in combination as compared with use of a single setting material. This tendency became strong when polyquaternium-11 at a higher concentration was used. Brittleness, which occurred with time when only VP/VA copolymer was used, was offset by using polyquaternium-11 as other setting materials. Use of a VP/VA copolymer and polyquaternium-11 in combination reduced the brittleness observed with a VP/VA copolymer and inhibited "flaking" - the appearance of dandruff-like flakes caused by flaking off of resin.

We prepared hairstyling products by incorporating the effects of combined use. When we conducted sensory evaluation on those products, positive results were obtained in terms of setting function and usability including prevention of flaking.

We need to consider not only functionality but also compatibility, stability and safety when choosing a resin for use in actual hairstyling products. To select appropriate setting materials suited for accomplishing an end and produce hairstyling products that meet consumers' demands, we consider that this device for the bending test is extremely effective.

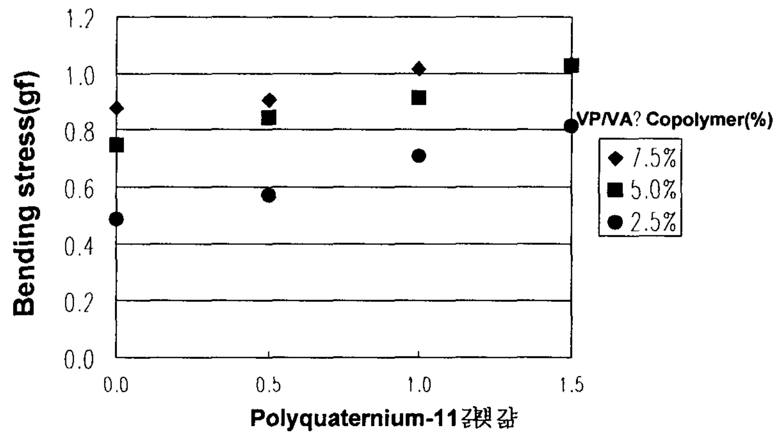

Fig.10 Effect on initial bending stress when setting materials were used in combination

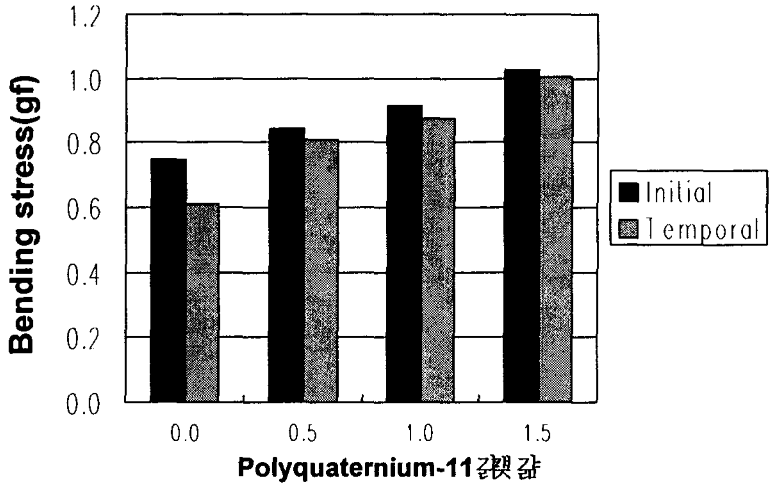

Fig.11 Comparison of results of initial bending stress and temporal bending stress when setting materials were used in combination. (VP/VA copolymer 5%)

Conclusions

In this study, we designed an evaluation method of the setting function of hairstyling products, based on an original theory on changes in bending stress observed when a load with continuous bending is applied to human hair. A device to measure bending stress has been developed to quickly and objectively evaluate the condition of human hair, particularly its dynamic properties such as the setting function following the application of hairstyling products. This device generates a load with continuous bending while applying a pendulum motion to a hair tress, one end of which is anchored. The setting function and holding power of hairstyling products were evaluated using this device.

The results of evaluation using this device showed a high correlation with the results obtained by sensory evaluation. Changes in holding power of hairstyling products over time were also detected using this device. Therefore, we conclude that evaluation using this device can substitute for sensory evaluation, and prompt objective evaluation is possible with this device. We also found that this method is excellent in terms of evaluation of functionality and usability of hairstyling products, and is expected to be useful in the development of hairstyling products.

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