J. Soc. Cosmet. Chem., **28**, 415–425 (August 1977)

The physical properties of fingernails
I. Apparatus for physical measurements

MICHAEL J. MALONEY and ELMER G. PAQUETTE *Bjorksten Research Laboratories Inc., P.O. Box 9444, Madison, WI 53715;* and ALBERT SHANSKY *Bettswood Road, Norwalk, CT 06851.*

Received September 30, 1976.

Synopsis

Miniature APPARATUS for measuring the PHYSICAL PROPERTIES of FINGERNAILS have been developed and tested. Included are a device for cutting test specimens; a template for preparing tensile bar samples; apparatus for performing flexural, tensile, and tearing tests; and a device for determining impact absorption. Whenever possible, methods were based on standard testing procedures so that recognized interpretative formulae could be used for analyzing experimental results. The range of physical properties found for the fingernails tested are as follows: flexural strength 4,928 to 17,653 psi; tensile strength 4,464 to 17,081 psi; tearing resistance 274.3 to 676.2 lb/in. and impact absorption (rebound ratio) 0.4632 to 0.7273.

INTRODUCTION

A number of investigators have reported on studies involving the human fingernail. While all of these studies have proved revealing, they have, as a group, suffered from one or more of the following limitations: (1) inadequate number of tests or subjects, (2) inadequate measuring techniques, (3) inadequate analysis or interpretation of results.

Bean (1) has meticulously studied the growth of his left thumbnail over a period of twenty-five years. His observations regarding the effect of age and a case of mumps are noteworthy and his philosophy amusing. Caputo and Dadati (2) and Jarrett and Spearman (3) have made significant contributions to the understanding of nail structure. Donsky (4) and Lazar (5) have sounded a warning note regarding the use of so-called nail hardeners. Dixon (6) attempted to evaluate the effect of a commercial nail food on nail splitting. While her results indicated no beneficial effect, she concluded that the trial was an educational success.

Michaelson and Huntsman (7) attempted to provide a numerical answer to the question of whether or not gelatin in the diet has an effect on nail hardness. They used a Knoop indentor to evaluate hardness, and while they concluded that gelatin increases hardness, the validity of their data has been questioned by Newman and Young (8). These latter authors have proposed that flexural measurements of fingernails should provide the maximum information in the most direct manner (9). Baden (10) also studied nail flexibility and developed two additional methods for measuring modulus of elasticity.

Having independently arrived at the same conclusion as Baden, Newman, and Young, and having designed and built an apparatus for measuring flex strength, the authors support their conclusions regarding the value of flexural data. In addition, the authors have also devised apparatus and techniques for measuring tensile strength, impact absorption, and tearing strength of fingernails. Three of these properties are obtained by adapting a commercially available testing machine (the Instron tester). We consider this feature particularly important, since it allows other workers to perform comparable experiments. The fourth test (impact absorption) employs apparatus of our own design. However, the innate simplicity of the device insures that it could be easily duplicated by others.

Of the 4 tests, flexural strength and impact absorption have been demonstrated to be nondestructive. This feature allows the same nail to be tested several times and is invaluable for experiments, where it is desirable to determine the effect of exposure to various environments. Also, since each sample can serve as its own control, the number of experiments necessary to achieve statistical significance is greatly reduced.

The nail samples used for our studies were obtained from both living donors (large clippings) and cadavers. The donors ranged in age from 28 to 98 years and were about evenly divided between males and females.

DESCRIPTION OF THE APPARATUS

FLEXURAL TESTING APPARATUS

The procedure for determining flexural properties of plastics is described in ASTM method D-790 (11). The specifications call for a specimen, in the form of a rectangular bar, which is positioned on 2 supports and a load applied at the midpoint of the span.

The apparatus normally used for these tests is far too large to accommodate fingernails. To overcome this problem, therefore, a miniature fixture (Fig. 1), to be used in conjunction with an Instron tester was designed and fabricated. Even though the apparatus is much smaller than that normally used, the ratio of sample thickness to support radii is not changed, and the standard interpretive formulae may be employed.

SAMPLE CUTTING APPARATUS

In order to obtain reasonable accuracy when performing flexural tests, it is extremely important that the cut sides of the test specimens be as nearly parallel as possible. In our opinion, the method employed by Newman and Young (wherein the surfaces were sanded lightly) was not entirely satisfactory. Therefore, we have developed a device (shown in Fig. 2), which employs two rigidly mounted razor blades to accurately cut parallel samples for our tests.

In using the apparatus, a fingernail clipping is first conditioned by soaking it in distilled water. Then the clipping is flattened by clamping it between 2 sheets of clear plastic for at least 20 min. The flattened nail is carefully positioned on the cutting edges and

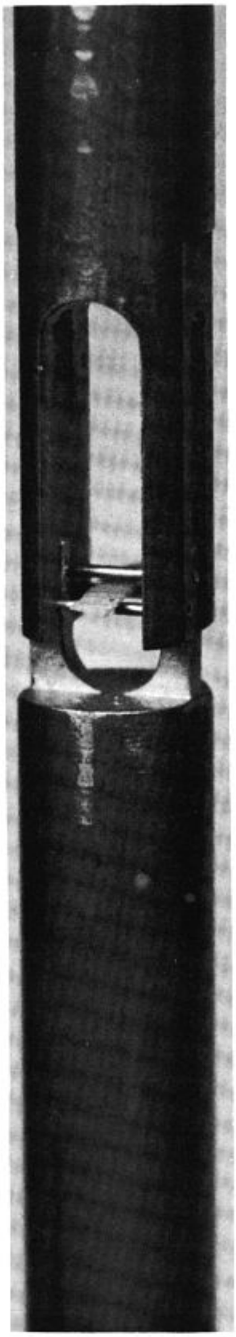

Figure 1. Apparatus for measuring the flexual properties of fingernails

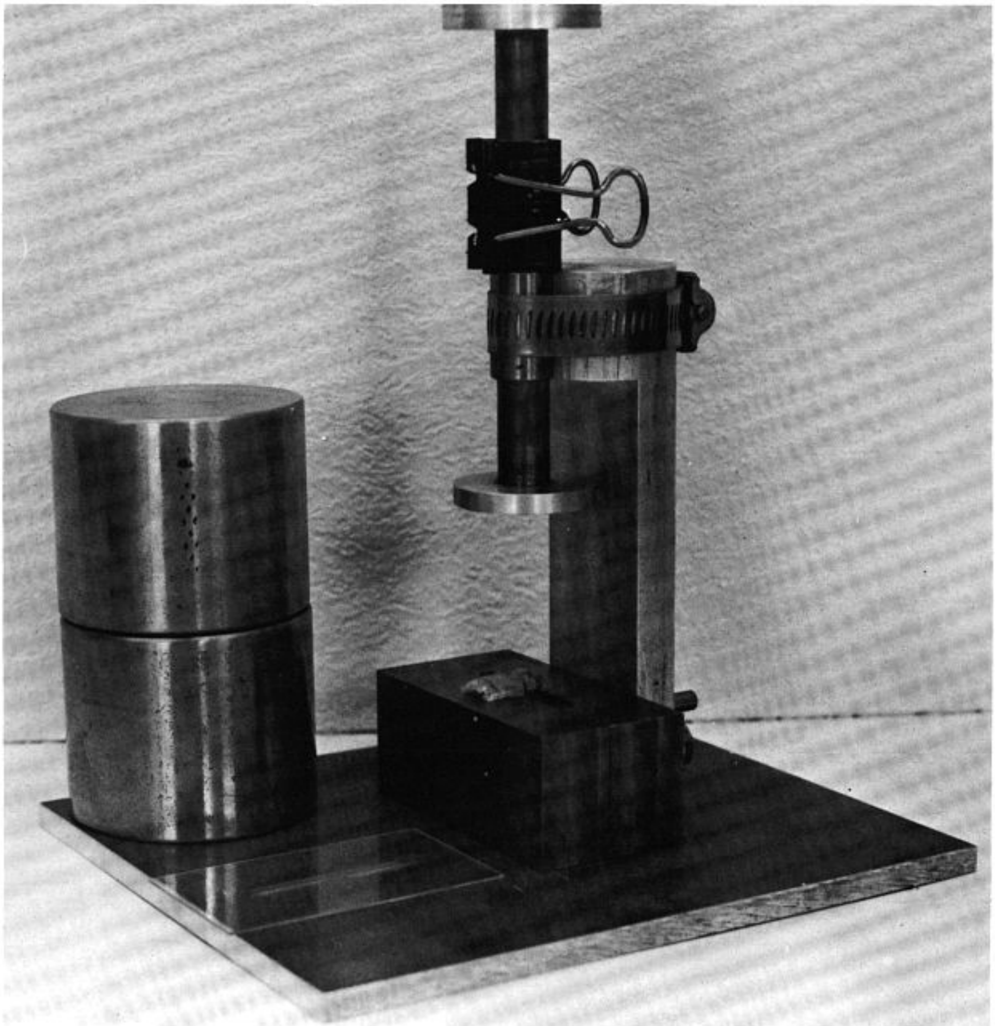

Figure 2. Apparatus for cutting fingernail test specimens

covered with a rigid plastic backing plate. A movable plunger is brought in contact with the plastic, and a weight is applied to the plunger. The weight forces the sample between the blades resulting in a clean sample, which is parallel to within a few hundred thousands of an inch. All of the specimens used for these experiments were conditioned to 25°C and 65 per cent RH before testing.

FLEXURAL TESTING EXPERIMENTS

As soon as a sufficient quantity of fingernail samples had been cut and conditioned initial experiments aimed at determining the capabilities of the apparatus were begun. During testing, the samples were subjected to a total deflection of 0.02 in. at a crosshead speed of 0.05 in./min. The testing machine is calibrated to measure forces in the range of 0 to 2 lb and a strip chart recorder, driven at 10 in./min, provides a load/deflection curve. By combining low crosshead speed with a high rate of chart traverse, excellent resolution of stress–strain data are obtained. Also, since the samples are only slightly deflected during testing, no physical damage is done to the nails.

Initially, tangent modulus of elasticity, stress at a given strain, and flexural yield strength determinations were calculated for each sample. Ultimately, however, we determined that the flexural yield strength values were the most representative and thereafter only that value was determined. In our preliminary experiments with this apparatus, we tested a total of 92 different fingernail samples having a range of flexural yield strengths from 4,928 to 17,653 lb/in.^{2}

TENSILE TESTING APPARATUS

The procedure for determining the tensile properties of plastics is described in ASTM method D-638 (12). The specifications call for a specimen in the form of a rectangular bar having a reduced cross-section at the point where fracture is desired.

As with the flexural tester, the apparatus normally used for cutting the test specimens and performing the tests is far too large to accommodate fingernails. Once again, therefore, we designed and fabricated a series of miniature fixtures for sample preparation and testing.

TENSILE BAR FABRICATION

To obtain the reduced cross-section (dog bone) specimens necessary for this test we constructed the device shown in Fig. 3. The rectangular specimens are clamped in the template, and the necessary excess material removed by gently filing with a tool makers file. Since the samples are quite small, it is necessary to observe the work area through a low power microscope during the filing operation.

The resultant specimens are 0.032 in. wide in the reduced area and 0.100 in. wide in the area which is gripped in the tester. The 0.032 in. dimension was found to be crucial as samples having any larger cross-section were highly prone to jaw breaks.

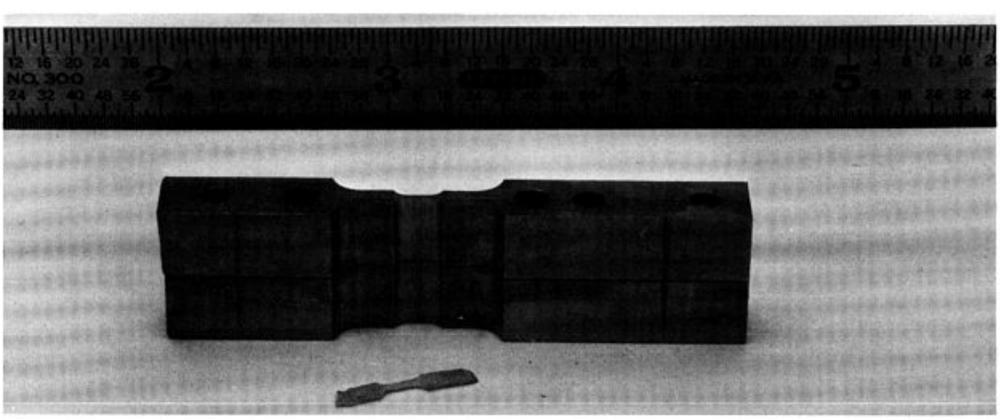

Figure 3. Template for preparing tensile samples from fingernails

TENSILE TESTING EXPERIMENTS

Our preliminary investigations indicated that the clamping mechanism would be the most important factor in both the tensile and tearing apparatus. We have found fingernails to be extremely plastic in nature. Therefore, when they are clamped between 2 flat surfaces, they almost immediately assume the new dimensions and slide from the clamp when a force is applied.

To alleviate this problem, it was necessary to construct a set of clamping jaws having directional serrated faces. The serrations act as miniature "teeth" and grip the nail securely without weakening it to such an extent that breakage takes place within the jaws.

Because of plastic deformation by the nails, it is necessary to insert shims to limit the penetration of the gripping "teeth." Each nail is measured, and then a shim selected which will limit the penetration to 0.005 in., since we have found that this is sufficient to insure a secure grip without propagating jaw breaks.

Figure 4 shows the apparatus performing a tensile test. All tests were conducted at a

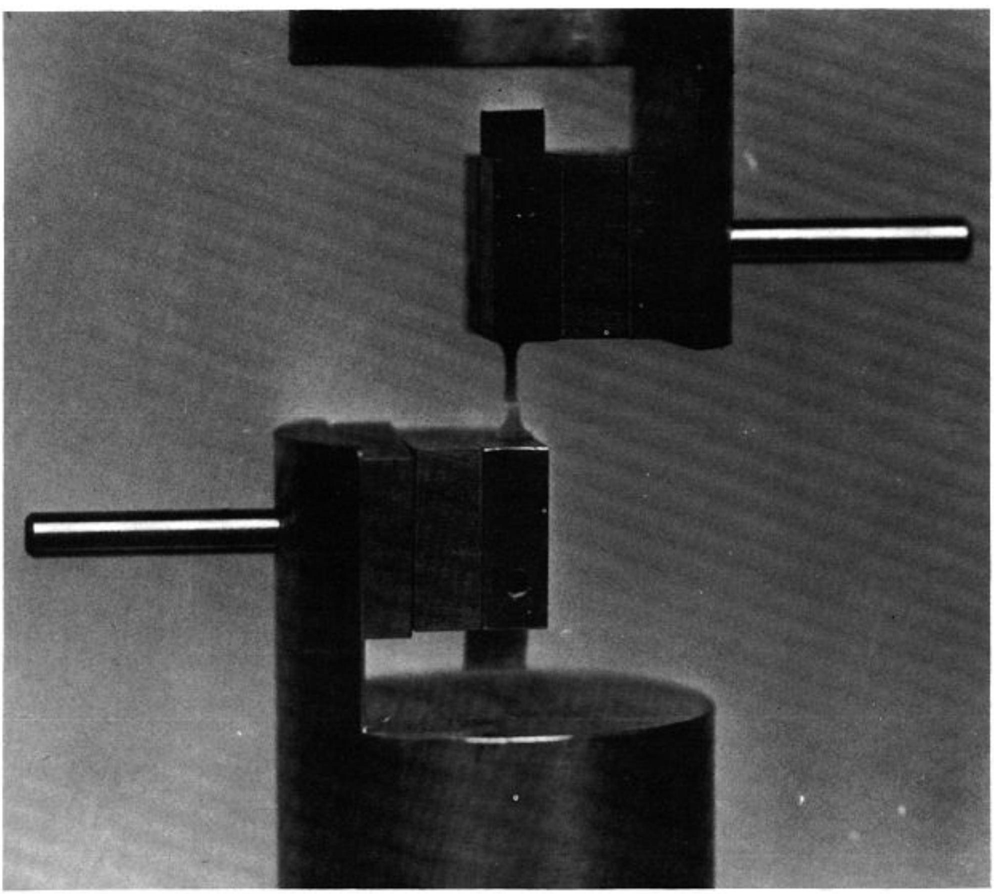

Figure 4. Apparatus for performing tensile tests on fingernails

crosshead speed of 0.2 in./min with the machine calibrated to measure forces in the range from 0 to 20 lb. In these initial tests, a total of 196 samples were tested. The tensile strength values determined from these samples ranged from 4,464 to 17,081 $lb/in.^2$

TEARING TEST APPARATUS

The objective of the tearing test is to simulate the action that occurs when a fingernail is torn. In order to gain a better understanding of the mechanisms involved, a "living" fingernail was torn *in situ,* and the results were carefully observed.

As a result of the *in situ* tearing experiment, we concluded that the action involved closely resembled that of a piece of paper being held in both hands and torn. Once the initial break has occurred, the stresses concentrate at the point of failure and propagate the tear along the path of least resistance.

In order to translate this action to a physical test, it was evident that the clamping jaws must be free to rotate so that the stresses could follow the line of the tear. This was achieved by attaching the jaws by means of a pin whose axis coincided with the edge of the nail where the tear would originate. Figure 5 shows the clamping jaws with 1 jaw open to reveal the clamping "teeth."

During the actual test, stress is applied to the edge of the nail until failure begins to occur. As the test proceeds, the jaws rotate concentrating the stress at the point where failure is occurring. Figure 6 shows the apparatus modified for tearing tests. The tests were conducted at a crosshead speed of 0.05 in./min with the machine calibrated to measure forces in the range from 0 to 20 lb.

TEARING TEST EXPERIMENTS

Specimens for the tearing experiments are prepared in the same way as those employed for the flexural strength test. In this case, however, there were no standard

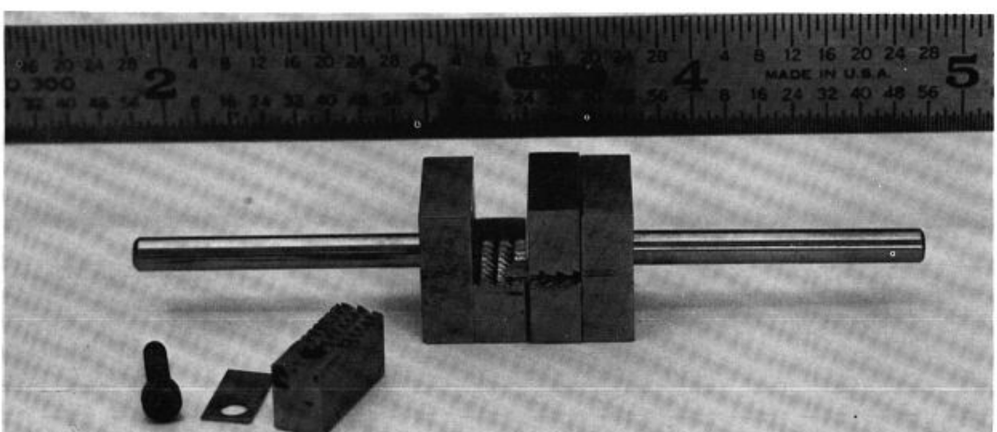

Figure 5. Clamping jaws used to secure tensile and tearing specimens for testing

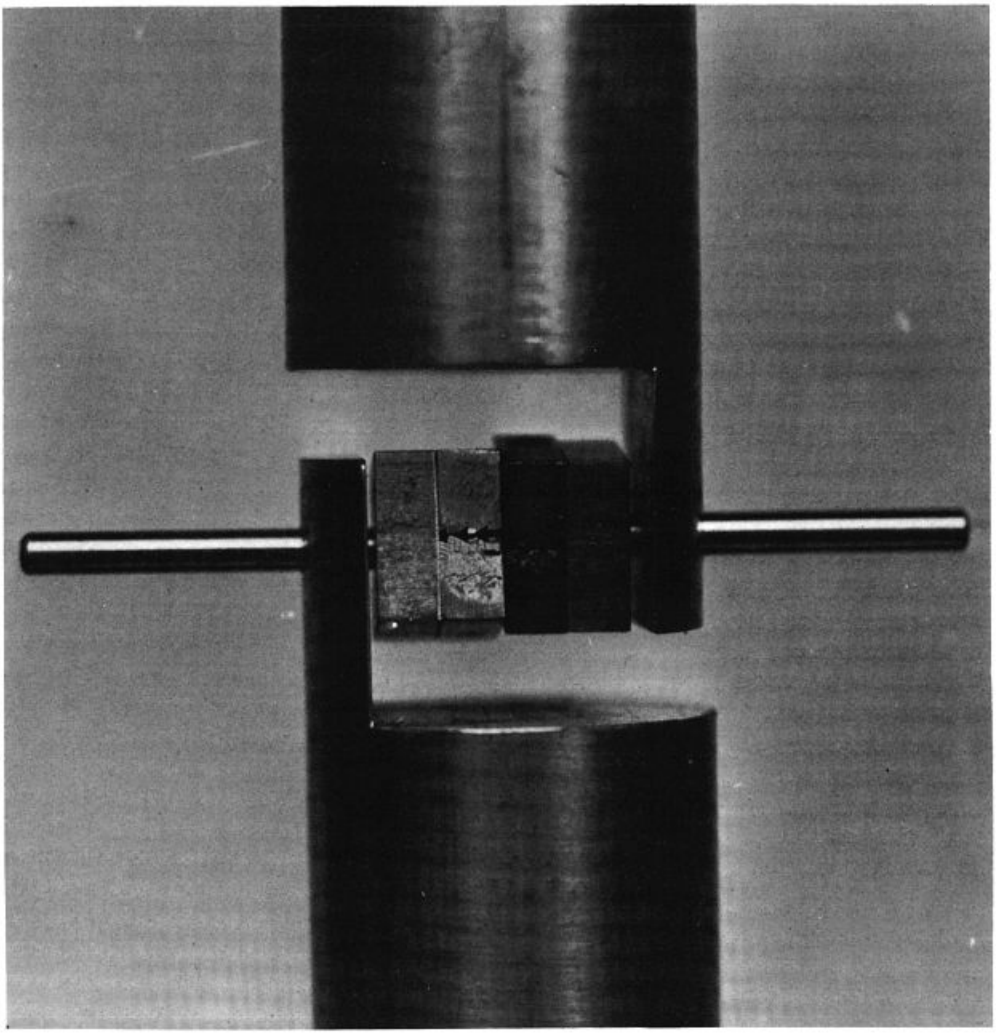

Figure 6. Apparatus for performing tearing tests on fingernails

methods to use as a guide, and we were forced to develop our own criteria for sample evaluation.

Before beginning the test, each fingernail specimen was carefully measured. The samples were then subjected to stress until failure occurred, and the force necessary was recorded. The results were plotted as tearing resistance in pounds per inch of nail thickness. A total of 15 fingernail samples were tested, and the values obtained ranged from 274.3 to 676.2 lb/in.

IMPACT ABSORPTION TESTER

The objective of the impact absorption test is to determine the effect of the impact of a swinging pendulum on a rigidly clamped sample. As with the previous tests, we found

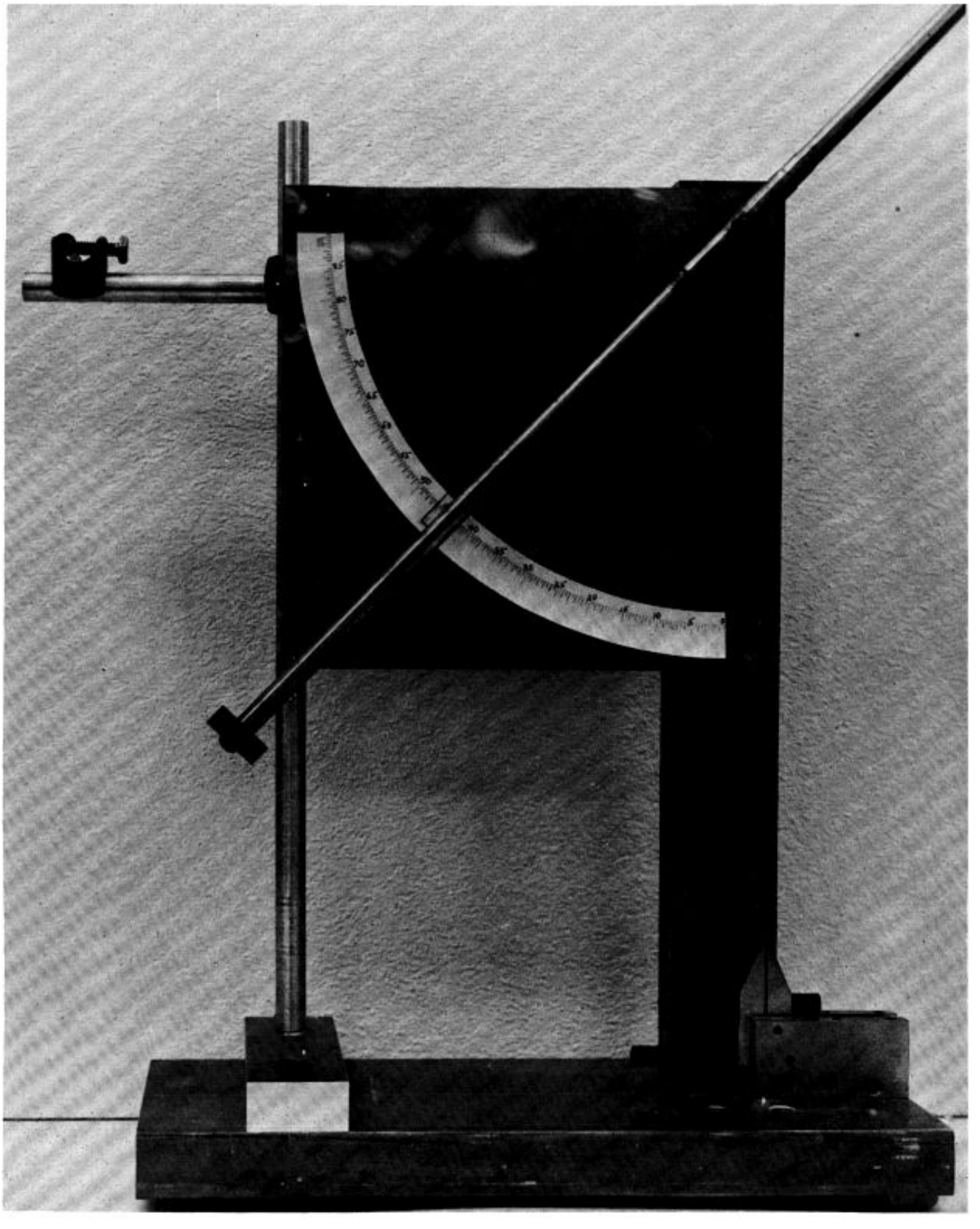

Figure 7. Apparatus for performing impact absorption experiments

that there was no suitable equipment available for testing samples of this size. Unlike the previous tests, however, this experiment could not be performed in the Instron or by modifying any other existing equipment. The simple apparatus which we have developed for this purpose is shown in Fig. 7.

IMPACT ABSORPTION EXPERIMENTS

The operation of the apparatus is as follows: a conditioned and inspected fingernail sample is placed in the clamp at the lower right hand side of the tester. The sample is clamped so that 1/8 in. of the nail protrudes from the top of the clamp. The pendulum, which has been resting in a horizontal position on the stop at the upper left side of the apparatus, is released and strikes the sample 1/16 in. above the clamp.

After striking the sample, the pendulum rebounds, and the rebound is observed and recorded. The pendulum continues to strike the sample, and the continually decreasing rebounds are observed and recorded. We have found it convenient to use a tape recorder to preserve the operator's observations, since it allows him to devote full attention to the mechanism.

The actual rebound in degrees is converted to rebound ratio by dividing the height in degrees of observed rebound by height in degrees of the starting point. For example, if the first rebound was observed to be 56.4 degrees, dividing by the starting point (90°) we would obtain a rebound ratio of 0.6267. If the second rebound was then observed to be 35.2 degrees, dividing by the starting point (56.9°), we would obtain a value of 0.6241.

The first 5 rebounds are converted in this manner, and the rebound ratios averaged, and the standard deviation determined. The procedure is repeated 3 times for each sample in order to reduce the chances of error due to an incorrect measurement and as a check against possible sample degradation due to the test itself.

In the experiments performed to date, a total of 64 different fingernail samples have been tested. The rebound ratio values obtained have ranged from 0.4632 to 0.7273.

SUMMARY

We have described 4 pieces of apparatus for measuring physical properties of fingernails. We have also presented a brief description of the operation of each apparatus and a range of experimental results which we have obtained from each. In our opinion, the tests provide a much needed addition to the state of the art in this area, and we hope that others will find them as useful as we have.

We regret that, due to space limitations, we could not include statistical interpretations of the results obtained. We are currently preparing another paper in which we intend to include this information. Also included will be data demonstrating differences in physical properties attributable to age and sex of the donor as well as hand and digit of nail origin.

ACKNOWLEDGMENTS

The authors wish to express their gratitude to Del Laboratories, Inc., who provided the financial support, which made this program possible, and to Patrick Harding who prepared the photographs of the apparatus.

References

(1) W. B. Bean, Nail growth; twenty-five years' observation, *Arch. Intern. Med.*, **122**, 359–61 (1968).
(2) R. Caputo and E. Dadati, Preliminary observations about the ultrastructure of the human nail plate treated with thioglycolic acid, *Arch. Klin. Exp. Dermatol.*, **231**, 344–54 (1968).
(3) A. Jarrett and R. I. C. Spearman, The histochemistry of the human nail, *Arch. Dermatol.*, **94** (1966).
(4) H. Donsky, Onycholysis due to nail hardener, *Can. Med. Ass. J.*, **96**, 1375–6 (1967).
(5) P. Lazar, Reactions to nail hardeners, *Arch. Dermatol.*, **94**, 446–8 (1966).
(6) S. Dixon, Nail-splitting: a survey, *Nursing Times*, 1760–1 (1967).
(7) J. B. Nichaelson and D. J. Huntsman, New aspects of the effects of gelatin on fingernails, *J. Soc. Cosmet. Chem.*, **14**, 443 (1963).
(8) S. B. Newman and R. W. Young, Indentation hardness of the fingernail, *J. Invest. Dermatol.*, **49**, 103–5 (1967).
(9) R. W. Young, S. B. Newman, and R. J. Capott, Strength of fingernails, *J. Invest. Dermatol.*, **41**, 358–60 (1963).
(10) H. P. Baden, The physical properties of nail, *J. Invest. Dermatol.*, **55**, 115–22 (1970).
(11) Standard method of test for flexural properties of plastics, *Book of ASTM Standards*, **27**, 272–9 (1970).
(12) Standard method of test for tensile properties of plastics, *Book of ASTM Standards*, **27**, 169–82 (1970).