Physical property comparison of 11 soft denture lining materials as a function of accelerated aging

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Soft denture-lining materials are an important treatment option for patients who have chronic soreness associated with dental prostheses. Three distinctly different types of materials are generally used. These are plasticized polymers or copolymers, silicones, or polyphosphazene fluoroelastomer. The acceptance of these materials by patients and dentists is variable. The objective of this study is to compare the tensile strength, percent elongation, hardness, tear strength, and tear energy of eight plasticized polymers or copolymers, two silicones, and one polyphosphazene fluoroelastomer. Tests were run at 24 hours after specimen preparation and repeated after 900 hours of accelerated aging in a Weather-Ometer device. The data indicated a wide range of physical properties for soft denture-lining materials and showed that accelerated aging dramatically affected the physical and mechanical properties of many of the elastomers. No soft denture liner proved to be superior to all others. The data obtained should provide clinicians with useful information for selecting soft denture lining materials for patients. (J PROSTHET DENT 1993;69:114-9.)

The success of complete or partial dentures depends on esthetics, comfort, and function. Unfortunately, the health of the supporting tissues may be adversely affected by high stress concentrations during function.[1, 2] Chronic soreness is a significant problem for denture patients with diabetes or other debilitating diseases and for many geriatric patients.[3, 4] In addition, patients with heavy bruxing or clenching habits may suffer the same consequence. The soft denture-bearing mucosa is confined between the hard denture base and bone. During function, considerable damage can be done to the supporting tissues resulting in chronic soreness, pathologic changes, and bone loss. The use of soft lining materials is designed to distribute functional and nonfunctional stresses more evenly and to have a dampening effect because of elastic behavior. These properties make soft denture lining materials useful for treating patients with (1) ridge atrophy or resorption, (2) bony undercuts, (3) bruxing tendencies, (4) congenital or acquired oral defects requiring obturation, (5) xerostomia, and (6) dentures opposing natural dentition in the opposing arch.[4]

Unfortunately, no products are available that will remain serviceable for extended periods of time.[5-10] At best, the available products are considered temporary expedients; their service expectancy does not compare with that of the hard denture base. Failures are associated with poor physical and mechanical properties that foul the lining materials by fungal and bacterial growth and bond poorly to denture base materials.[5]

The purpose of this investigation is to determine the specific physical and mechanical properties of 11 commercially available soft denture lining materials as a function of accelerated aging. The elastomers chosen for this study are all laboratory-processed lining materials and are marketed for extended service when compared with chairside denture lining materials. The data obtained from exposing these materials to the harsh environment of accelerated aging should provide clinicians with useful information when they are choosing soft denture lining materials for patients.

MATERIAL AND METHODS

Samples were processed according to the manufacturers' directions, stored in a humidor for 24 hours, then tested for tensile strength, percent elongation, hardness, tear strength, and tear energy before accelerated aging. After these baseline data were obtained, the tests were repeated after a second set of samples were subjected to an accelerated aging chamber (Model 25-WR, Weather-Ometer, Atlas Electric Devices Co., Chicago, Ill.). The weathering cycle was 900 hours of exposure to a xenon ultraviolet/visible light source at 110° F and 90% relative humidity. A programmed cycle of 18 minutes of distilled water spray was used during each 120 minute period.[11] A sample size of five specimens was used for each material for each test condition.

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Table I. List of materials and manufacturers

Material	Type	Batch No.	Company
Durasoft	Plasticized polymer or copolymer	5265	Astron Dental Wheeling, Ill. 60090
Coe Super	Plasticized polymer or copolymer	P101089A L060189A	Coe Company Chicago, Ill. 60658-1597
ProTech	Plasticized polymer or copolymer	P816894 L502898	Pro-Tech, Inc. Dental Products Division Centereach, N.Y. 11720
Justi Soft	Plasticized polymer or copolymer	P32366 L320	Justi Products/American Tooth Industries Oxnard, Calif. 9303
Verno-Soft	Plasticized polymer or copolymer	P29006 L092989	Vernon-Benshoff Co. Albany, N.Y. 12201
Velvesoft	Plasticized polymer or copolymer	None	Oral Health U.S.A., Inc. Piscataway, N.J. 08854
Soft-Pak	Plasticized polymer or copolymer	P359901 L360901	General Dental Products Elk Grove, Ill. 60007
Flexor	Plasticized polymer or copolymer	945004	Ticonium Co. Albany, N.Y. 12201
Prolastic	Silicone	890301	Young Dental Maryland Heights, Mo. 63043
Molloplast-B	Silicone	900103	Buffalo Dental Mfg. Co. Inc. Syosset, N.Y. 11791
Novus	Polyphosphazene fluoroelastomer	31489A	Hygenic Corp. Akron, Ohio 44310

Tensile specimens were dumbbell shaped as specified in American Society for Testing and Materials (ASTM): 412-66, but modified to provide for a smaller specimen to conserve material. The specimen size was 89 mm long × 3 mm × 3 mm in cross section. The specimens were placed in tension in a universal tensile testing machine (Instron Corp., Canton, Mass.) at a strain rate of 50 cm/minute. Percent elongation values were obtained by attaching an extensometer to the tensile specimen. Hardness was determined with a Shore-A durometer according to ASTM: D2240-64T. The specimen thickness was 1 cm. Tear resistance was determined according to ASTM: D624-54. The notched specimen geometry was that of die C but modified to provide a smaller sample to conserve material. The strain rate was 50 cm/minute and the universal testing machine mentioned was used. Tear energy was determined according to Webber et al.[12] Webber's method of determining tear energy takes into account the highly elastic nature of the elastomer specimens. The tear specimen was 1 mm thick × 25 mm wide × 75 mm long with a cut down the center. The result was a trouser-shaped specimen. (This test is sometimes referred to as a pantstear test.) The legs of the specimen were bent in opposite directions and stressed with an Instron universal testing machine, which initiates a tear at the end of the cut.

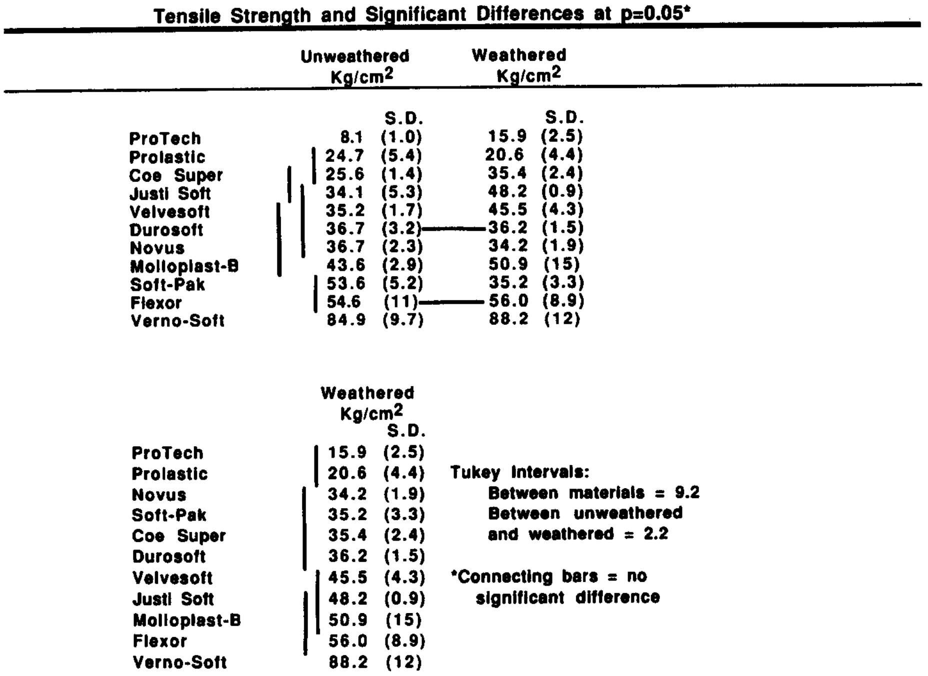
All data were tabulated and statistical comparisons of the means were made by use of a two-way ANOVA and calculated Tukey intervals.[13] The soft lining materials that were compared are listed according to type and manufacturer in Table I.

RESULTS

The tensile strength of the soft lining materials ranged from 8.1 kg/cm^2 (unweathered) to 15.9 kg/cm^2 (weathered) for ProTech lining material to 84.9 kg/cm^2 (unweathered) to 88.2 kg/cm^2 (weathered) for Verno-Soft lining material (Fig. 1). Most of the soft lining materials ranged between 25 kg/cm^2 and 56 kg/cm^2 tensile strength for both unweathered and weathered conditions. Most lining materials demonstrated an increase in tensile strength after weathering, with Coe Super Soft, Justi Soft, and Velvesoft lining materials having the greatest increases. Soft-Pak lining material decreased in tensile strength after weathering.

The percent elongation varied between 150% to 542% for unweathered specimens and 125% to 530% for weathered specimens (Fig. 2). Before and after aging, Verno-Soft lining material had the lowest elongation and Flexor had the highest. The elongation of most lining materials decreased after weathering with the exception of Molloplast-B, which increased from 326% to 440%.

A wide range of hardness was observed for the soft lining materials. The softest material was Prolastic, which had a Shore-A hardness of 25 units (unweathered) and 30 units (weathered) (Fig. 3). The hardest material was Verno-Soft, with a Shore-A hardness of 95 units for both unweathered



Tensile Strength and Significant Differences at p=0.05*

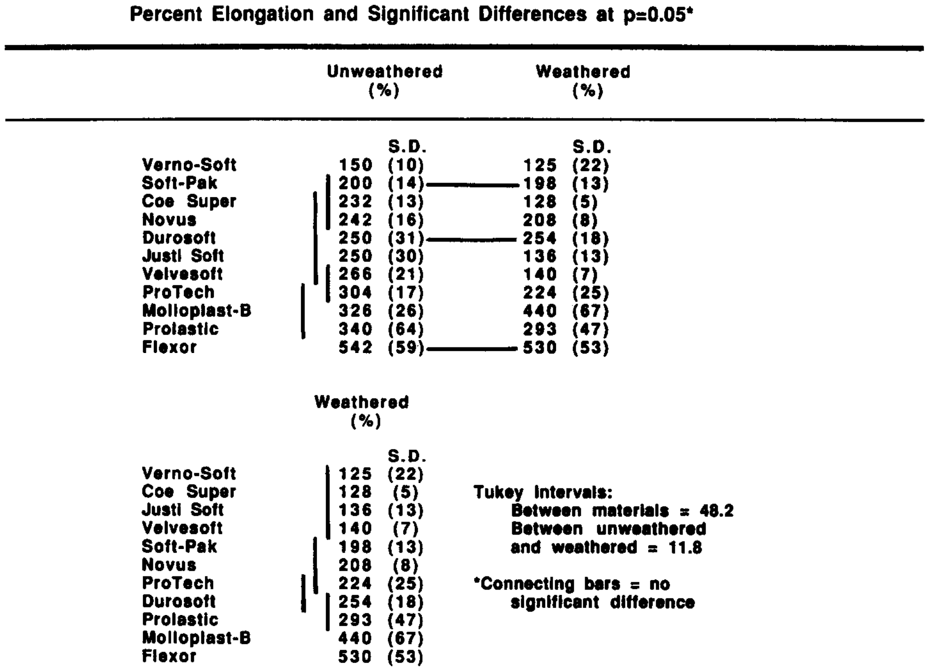
	Unweathered Kg/cm²	S.D.	Weathered Kg/cm²	S.D.
ProTech	8.1	(1.0)	15.9	(2.5)
Prolastic	24.7	(5.4)	20.6	(4.4)
Coe Super	25.6	(1.4)	35.4	(2.4)
Justi Soft	34.1	(5.3)	48.2	(0.9)
Velvesoft	35.2	(1.7)	45.5	(4.3)
Durosoft	36.7	(3.2)	36.2	(1.5)
Novus	36.7	(2.3)	34.2	(1.9)
Molloplast-B	43.6	(2.9)	50.9	(15)
Soft-Pak	53.6	(5.2)	35.2	(3.3)
Flexor	54.6	(11)	56.0	(8.9)
Verno-Soft	84.9	(9.7)	88.2	(12)

	Weathered Kg/cm²	S.D.
ProTech	15.9	(2.5)
Prolastic	20.6	(4.4)
Novus	34.2	(1.9)
Soft-Pak	35.2	(3.3)
Coe Super	35.4	(2.4)
Durosoft	36.2	(1.5)
Velvesoft	45.5	(4.3)
Justi Soft	48.2	(0.9)
Molloplast-B	50.9	(15)
Flexor	56.0	(8.9)
Verno-Soft	88.2	(12)

Tukey Intervals:
Between materials = 9.2
Between unweathered and weathered = 2.2

*Connecting bars = no significant difference

Fig. 1. Tensile strength and significant difference at $p = 0.05$.



Percent Elongation and Significant Differences at p=0.05*

	Unweathered (%)	S.D.	Weathered (%)	S.D.
Verno-Soft	150	(10)	125	(22)
Soft-Pak	200	(14)	198	(13)
Coe Super	232	(13)	128	(5)
Novus	242	(16)	208	(8)
Durosoft	250	(31)	254	(18)
Justi Soft	250	(30)	136	(13)
Velvesoft	266	(21)	140	(7)
ProTech	304	(17)	224	(25)
Molloplast-B	326	(26)	440	(67)
Prolastic	340	(64)	293	(47)
Flexor	542	(59)	530	(53)

	Weathered (%)	S.D.
Verno-Soft	125	(22)
Coe Super	128	(5)
Justi Soft	136	(13)
Velvesoft	140	(7)
Soft-Pak	198	(13)
Novus	208	(8)
ProTech	224	(25)
Durosoft	254	(18)
Prolastic	293	(47)
Molloplast-B	440	(67)
Flexor	530	(53)

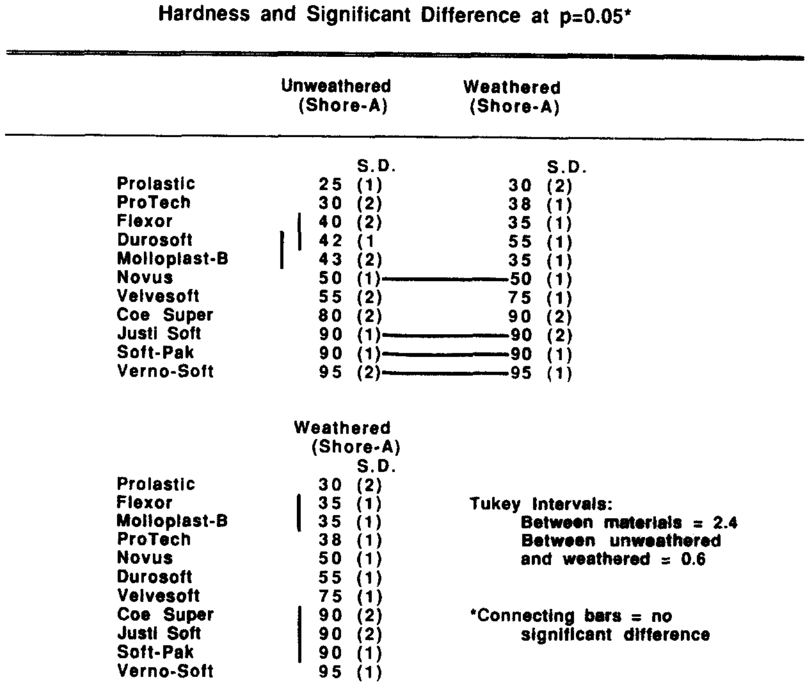
Tukey Intervals:
Between materials = 48.2
Between unweathered and weathered = 11.8

*Connecting bars = no significant difference

Fig. 2. Percent elongation and significant difference at $p = 0.05$.

and weathered specimens. Soft-Pak, Justi Soft, and Coe Super Soft lining materials also had high hardness values of 80 to 90 Shore-A units. The hardness of Novus, Justi Soft, Soft Pak, and Verno-Soft lining materials remained unchanged after weathering, whereas Molloplast-B and Flexor lining materials were softer. The remaining lining materials all increased in hardness as a function of weathering.

The tear resistance of all lining materials increased as a result of weathering except Prolastic, which decreased from 6.5 kg/cm^2 to 3.7 kg/cm and Soft-Pak material, which decreased from 11.7 kg/cm to 9.2 kg/cm (Fig. 4). Most lin-



Hardness and Significant Difference at p=0.05*

	Unweathered (Shore-A)	S.D.	Weathered (Shore-A)	S.D.
Prolastic	25	(1)	30	(2)
ProTech	30	(2)	38	(1)
Flexor	40	(2)	35	(1)
Durosoft	42	(1	55	(1)
Molloplast-B	43	(2)	35	(1)
Novus	50	(1)	50	(1)
Velvesoft	55	(2)	75	(1)
Coe Super	80	(2)	90	(2)
Justi Soft	90	(1)	90	(2)
Soft-Pak	90	(1)	90	(1)
Verno-Soft	95	(2)	95	(1)

	Weathered (Shore-A)	S.D.
Prolastic	30	(2)
Flexor	35	(1)
Molloplast-B	35	(1)
ProTech	38	(1)
Novus	50	(1)
Durosoft	55	(1)
Velvesoft	75	(1)
Coe Super	90	(2)
Justi Soft	90	(2)
Soft-Pak	90	(1)
Verno-Soft	95	(1)

Tukey Intervals:
Between materials = 2.4
Between unweathered and weathered = 0.6

*Connecting bars = no significant difference

Fig. 3. Hardness and significant difference at $p = 0.05$.

ing materials had a tear resistance of 7 to 15 kg/cm except Verno-Soft, which exceeded all others at 26.3 kg/cm (unweathered) and 30.1 kg/cm (weathered).

There was a wide range of values for tear energy. Molloplast-B material had the lowest value of 1.4 M ergs/cm^2 (unweathered) and 1.7 M ergs/cm^2 (weathered) (Fig. 5). Verno-Soft material had the highest tear energy at 40.4 M ergs/cm^2 (unweathered) and 51.7 M ergs/cm^2 (weathered). Most of the lining materials increased in tear energy as a result of weathering.

DISCUSSION

There was an overlapping of properties, which was expected, between the three different types of soft lining materials. The tensile strength of the silicone lining material was only slightly higher than that of the copolymers. One copolymer (Verno-Soft) surpassed all others in tensile strength (84.9 kg/cm^2 unweathered, 88.2 kg/cm^2 weathered) (Fig. 1). The increase in tensile strength after weathering was probably the result of continued polymerization or loss of plasticizers. This may account for the decrease in percent elongation and the increase in hardness, tear resistance, and tear energy among most of the soft lining materials after weathering.

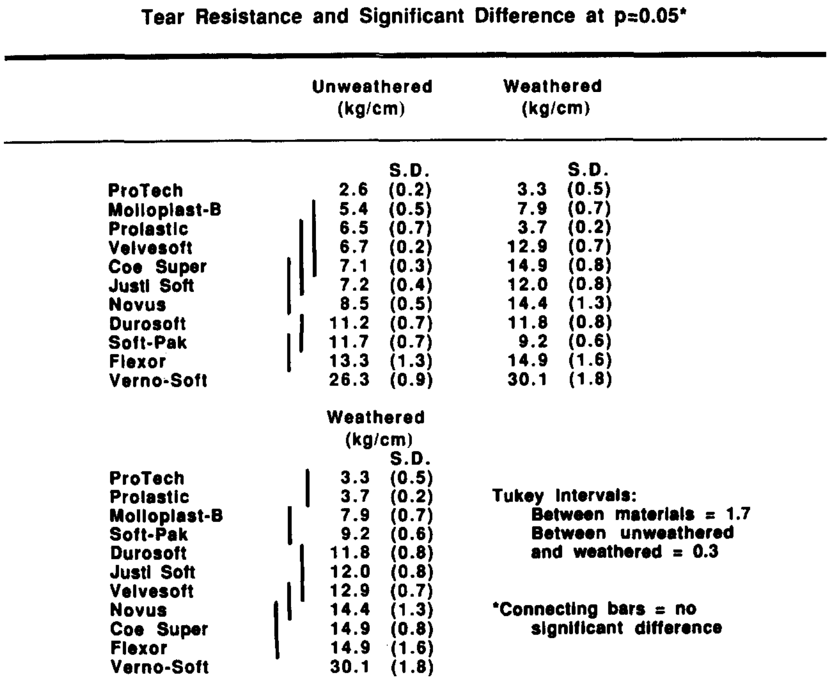
Both silicone elastomers (Prolastic and Molloplast-B) had high percent elongation (Fig. 2) and lower Shore-A hardness values (Fig. 3) than most of the copolymers and the one polyphosphazene fluoroelastomer. The combination of high percent elongation and low Shore-A hardness value indicates a soft denture lining material. This combination of properties could be used to select a denture lining material with a high degree of softness if the clinician desired this property.

Tear resistance and tear energy values increased after weathering, probably as a result of continued polymerization and/or loss of plasticizers (Figs. 4 and 5). Tear and tensile values provide information on the strength of the denture lining material, but strength values are not sufficient because high bond strength with the denture base material is also required.

Among the copolymers, ProTech lining material had the lowest tensile strength and above average elongation, but it was also one of the softest lining materials. By comparison Verno-Soft material had the highest tensile strength, tear resistance, and tear energy, but it had the lowest elongation. It was the hardest among the copolymers, silicones, and the polyphosphazene. Novus, the only polyphosphazene lining material available on the market at this time, compared favorably with the average properties in all tests.

Because of the extreme range in physical properties between the lining materials tested, no one lining material is superior to all others. If a selection is made on the basis of softness alone, ProTech copolymer or Prolastic silicone materials would be the choices. However, both of these lining materials had low tensile strength, tear resistance, and tear energy. If tear properties are used as a basis for selection, Verno-Soft and Flexor exceed all other lining materials. Verno-Soft material had the highest hardness value of all lining materials tested (95 Shore-A units).

The success or failure of soft lining materials is not de-



Tear Resistance and Significant Difference at p=0.05*

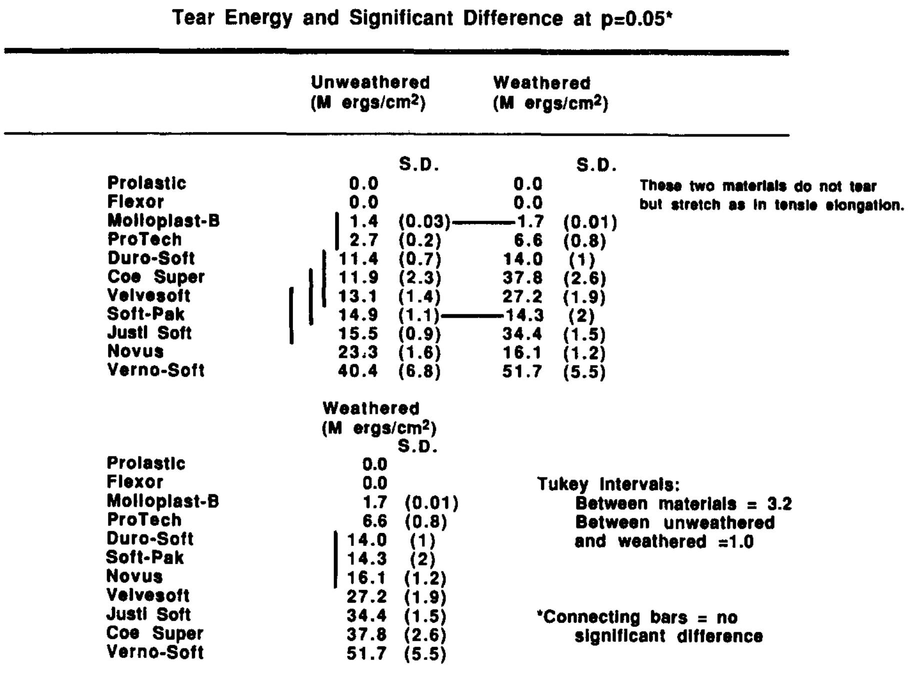
	Unweathered (kg/cm)	S.D.	Weathered (kg/cm)	S.D.
ProTech	2.6	(0.2)	3.3	(0.5)
Molloplast-B	5.4	(0.5)	7.9	(0.7)
Prolastic	6.5	(0.7)	3.7	(0.2)
Velvesoft	6.7	(0.2)	12.9	(0.7)
Coe Super	7.1	(0.3)	14.9	(0.8)
Justi Soft	7.2	(0.4)	12.0	(0.8)
Novus	8.5	(0.5)	14.4	(1.3)
Durosoft	11.2	(0.7)	11.8	(0.8)
Soft-Pak	11.7	(0.7)	9.2	(0.6)
Flexor	13.3	(1.3)	14.9	(1.6)
Verno-Soft	26.3	(0.9)	30.1	(1.8)

	Weathered (kg/cm)	S.D.
ProTech	3.3	(0.5)
Prolastic	3.7	(0.2)
Molloplast-B	7.9	(0.7)
Soft-Pak	9.2	(0.6)
Durosoft	11.8	(0.8)
Justi Soft	12.0	(0.8)
Velvesoft	12.9	(0.7)
Novus	14.4	(1.3)
Coe Super	14.9	(0.8)
Flexor	14.9	(1.6)
Verno-Soft	30.1	(1.8)

Tukey Intervals:
Between materials = 1.7
Between unweathered and weathered = 0.3

*Connecting bars = no significant difference

Fig. 4. Tear resistance and significant difference at $p = 0.05$.



Tear Energy and Significant Difference at p=0.05*

	Unweathered (M ergs/cm^2)	S.D.	Weathered (M ergs/cm^2)	S.D.
Prolastic	0.0		0.0	
Flexor	0.0		0.0	
Molloplast-B	1.4	(0.03)	1.7	(0.01)
ProTech	2.7	(0.2)	6.6	(0.8)
Duro-Soft	11.4	(0.7)	14.0	(1)
Coe Super	11.9	(2.3)	37.8	(2.6)
Velvesoft	13.1	(1.4)	27.2	(1.9)
Soft-Pak	14.9	(1.1)	14.3	(2)
Justi Soft	15.5	(0.9)	34.4	(1.5)
Novus	23.3	(1.6)	16.1	(1.2)
Verno-Soft	40.4	(6.8)	51.7	(5.5)

These two materials do not tear but stretch as in tensle elongation.

	Weathered (M ergs/cm^2)	S.D.
Prolastic	0.0	
Flexor	0.0	
Molloplast-B	1.7	(0.01)
ProTech	6.6	(0.8)
Duro-Soft	14.0	(1)
Soft-Pak	14.3	(2)
Novus	16.1	(1.2)
Velvesoft	27.2	(1.9)
Justi Soft	34.4	(1.5)
Coe Super	37.8	(2.6)
Verno-Soft	51.7	(5.5)

Tukey Intervals:
Between materials = 3.2
Between unweathered and weathered =1.0

*Connecting bars = no significant difference

Fig. 5. Tear energy and significant difference at $p = 0.05$.

termined entirely by the physical properties reported in this evaluation. Additional factors are equally important and must be considered. Bond strength between the lining material and denture base must be sufficient to prevent delamination during function. Creep compliance, dynamic modulus, water sorption, and stain resistance are also important factors. In addition, tissue compatibility and the germicidal nature of a lining material are not to be ignored. These factors are being studied.

The range of properties presented in this study indicates the wide choice of materials. The results of this study certainly support the need for a specification for long-term soft denture-lining materials. This study and future research may make the task of developing specific criteria possible.

CONCLUSIONS

1. Accelerated aging dramatically affected the physical and mechanical properties of many of the elastomers.
2. There is a wide range of physical properties for soft denture lining materials.
3. No single soft denture lining material proved to be superior to all others.
4. Essential physical properties required for soft denture lining materials have not been defined and the data obtained in this study would support the development of a specification for soft denture lining materials.

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