The Test of the Mechanical Properties of SY-28, SY-20 and MDX-4-4210 Silicone Elastomers

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Abstract: Objective The purpose of this study is to evaluate the physical and mechanical properties of SY-28 (Shore-A hardness being 28) and SY-20 (Shore-A hardness being 20) silicone elastomers and to compared with those of MDX－4-4210 in accordance with the American National Standards. **Methods** 5 test specimens of each silicone elastomer were prepared, then the major mechanical properties of the elastomer were tested and measured. The properties tested were selected because of their clinical significance for fabricating a facial prosthesis. **Results** The ultimate elongation tear strength and Shore-A hardness of SY-28 were better than those of MDX-4-4210 material. The tensile strength of SY-28 was similar to that of MDX-4-4210 material. The Shore-A hardness of SY-20 silicone elastomer was superior to that of MDX-4-4210 material. The tensile strength, ultimate elongation and tear strength were similar to those of MDX4-4-210 material. **Conclusion** Based on the present study, it appears that SY-28 and SY-20 silicone elastomers are suitable for use in fabricating of clinical prostheses. An improvement in the predictability of the mechanical behavior of SY-28 and SY-20 would further enhance the value of the material.

Key words: mechanical properties; silicone elastomers

INTRODUCTION

Although numerous advances in maxillofacial materials have been made in the past several years, the need for improvement continues. Currently, the most widely used materials are the silicone elastomers. The silicone elastomer MDX-4-4210 (Dow Corning, Midland, Mich.) appears to be the most popular and has most of properties ideal for use in extraoral prosthesis [1,2]. SY blending silicone elastomers are a series of maxillofacial prosthetic materials in order to meet all kinds of clinical demands in different types and parts of maxillofacial defect. In this study, two representative blending silicone elastomer materials, Shore-A hardness being 28 and 20, were selected to measure their mechanical properties in accordance with ASTM, and compared with those of MDX-4-4210 in the same condition.

MATERIALS AND METHODS

1. Materials

The silicone maxillofacial materials chosen for this study were MDX-4-4210 (Dow Corning, Midland, Mich.), SY-28 and SY-20.The materials were tested to determine the tensile strength, ultimate elongation, tear strength, and Shore-A hardness.

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2. Test methods

Five samples of each material were prepared.

Tensile strength (ASTM D412 [3])

Tensile strength is defined as the formula: F/A

Where F is the force required breaking the specimen and A is the cross-sectional area of the unstretched specimen.

Ultimate elongation (ASTM D412)

Ultimate elongation is calculated as follows: % elongation = $[(L-L_0)/ L_0] \times 100$

Where L is the observed distance between the benchmarks on the stretched specimens immediately before fracture and L_0 is the original distance between the benchmarks. Ultimate elongation was measured at the same time that the tensile strength test was performed. Tensile strength and dumbbell-shaped ultimate elongation specimens were prepared.

Tear strength (ASTM D624 [4])

Tear strength is determined by the formula: T=F/D

Where T is tear strength. F is the force required to break the specimen, and D is thickness of the specimen. Trouser-shaped specimens for tear strength were prepared.

Shore-A hardness (ASTM D2240 [5])

Ten measurements were made on each slab of material at least 6mm apart, and the mean value was determined. One piece (2 mm) and three pieces piled (6 mm) were measured according to ASTM specifications.

3. Statistical analysis

All data were first evaluated for homogeneity of variance by Bartlett's chi-square test. Then either an analysis of variance or Welch test was conducted. If a significant difference among means was found, a Neuman-Keul's multiple range test was performed to identify the differences between any of the groups at a significance level of p=0.05.

RESULTS

Table 1 presents means and standard deviation from the two tests for tensile strength and ultimate elongation. In Table 2, the tear strength values are shown. The results for Shore A hardness are given in Table 3.

The results showed that the mean values of SY-28 ($\overline{X}$ 4.1) and SY-20 ($\overline{X}$ 3.5) silicone elastomers were not significant with that of MDX-4-4210 ($\overline{X}$ 4.0) material for the tensile strength. For the ultimate elongation study, significant mean differences were found between SY-28 ($\overline{X}$ 570) and MDX-4-4210 ($\overline{X}$ 470) silicone elastomer at the $p<0.05$ level.

For the tear strength study, significant mean differences were found between SY-28 ($\overline{X}$ 17.0) and MDX-4-4210 ($\overline{X}$ 12.0) silicone elastomer at the $p<0.05$ level.

The mean values comparing results for the hardness test were significant at the $p<0.05$ level for SY-28 ($\overline{X}$ 28.0), SY-20 ($\overline{X}$ 20.0) and MDX-4-4210 ($\overline{X}$ 37.0) material.

Table 1 Tensile test results (Mean ± SD)

Material	Tensile strength (Mpa)	Ultimate elongation (%)
MDX-4-4210	4.0 ± 0.38	470 ± 35
SY-28	4.1 ± 0.32*	570 ± 39**
SY-20	3.5 ± 0.46*	450 ± 42*

*$p>0.05$; **$p<0.05$

Table 2 Tear strength results (Mean ± SD)

Material	Tear strength（KN/m）	*P*
MDX-4-4210	12.0 ± 3.5	
SY-28	17.0 ± 3.1	<0.05
SY-20	13.0 ± 3.5	>0.05

Table 3 Shore -A hardness results (Mean ± SD)

Material	Shore A hardness	*P*
MDX-4-4210	37.0 ± 5.2	
SY-28	28.0 ± 3.6	<0.05
SY-20	20.0 ± 1.8	<0.05

DISCUSSION

Currently most maxillofacial prostheses are made form silicone elastomers [6-8]. With the technology presently available, it may be possible to synthesize new elastomers with excellent potential for long term clinical success [9]. The technology of elastomers, it is a new practice to improve the properties of materials by blending various silicone elastomers.

Incorporation of silicone elastomers is a technology that various macromolecule silica gel polymer are mechanical blended to produce a compound silicone elastomer with new characters. Compound silicone elastomers possess excellent physical and mechanical properties, and its properties are convenient to be adjusted to meet clinical demand of various defects. SY series blending silicone elastomers are two series prosthetic materials (hard series: Shore-A hardness ranging 26, 28, 30; soft series: Shore-A hardness ranging 18, 20, 22.) that its hardness present ladder arrangement according to A component silicone elastomer's hardness (Shore-A hardness being 24).

In this study, the mechanical properties of SY-28 (Shore-A hardness being 28) and SY-20 (Shore-A hardness being 20) incorporating silicone elastomers were measured and compared with those of MDX-4-4210 material in accordance with ASTM. The four properties evaluated were tensile strength, ultimate elongation, tear strength, and Shore-A hardness. They are important mechanical properties and are useful for predicting how these materials will perform in service.

Insofar as materials for maxillofacial prosthetic rehabilitation are concerned, the tensile strength is important to express overall strength characteristics. The results showed that both SY-28 and SY-20 silicone elastomers were similar to that of MDX-4-4210 elastomer for the tensile strength property (Table 1). The next important property as a proposed specification for maxillofacial material is ultimate elongation, which is a measure consistent with flexibility and is an indicator of the overall flexibility of a prosthetic material with facial motion.

A facial prosthesis must be strong and tough but remain soft and pliable enough to accommodate the facial movements of the patient. Ultimate elongation defines the resistance of a facial prosthetic elastomer to rupture during use and maintenance. This property also defines the material's ability to accommodate facial movement [10]. Generally, a high ultimate elongation is more useful when restoring areas of the head and neck that move during function. In Table1, significant mean differences were found between SY-28 ($\overline{X}$ 570) and MDX-4-4210 ($\overline{X}$ 470) silicone elastomer at the $p<0.05$ level for the ultimate elongation study. Based on the present study, it appears that the ultimate elongation of SY-28 silicone elastomer is better than that of MDX-4-4210 material. And the ultimate elongation of SY-20 was similar to that of MDX4-4-210.

In the present study, it shows that SY-28 and SY-20 silicone elastomers are suitable for use in fabricating of clinical prostheses.

Tear strength is indicative of marginal integrity and durability of a material in clinical service. To obtain a thin margin that will blend easily onto surrounding facial structure, great strength is an important factor. This factor is required to camouflage the edge of the prosthesis with the skin. As a rule, higher tear test values indicate that the prosthodontist will be able to produce a fine finishing line with the skin. Although the material must possess reasonable tensile strength, tear strength is far more important in predicting the usefulness and durability of the material for facial prostheses. Comparison of values obtained in the tear strength test showed that SY-28 ($\bar{X}$ 17.0) silicone elastomer was significant higher than the MDX-4-4210 ($\bar{X}$ 12.0) material (Table Ⅱ). Significant mean differences were not found between SY-20 ($\bar{X}$ 13.0) and MDX-4-4210 ($\bar{X}$ 12.0) silicone elastomer for the tear strength.

Shore-A hardness is a simple test but one that can provide useful information on the softness or hardness of elastomers without the use of more sophisticated instruments. Lewis and Castleberry [11] stated that 25 to 35 Shore-A indentation units were desirable.

Facial features are composed of soft and hard substances, some mobile and some fixed. Physiologically and biomechanically, they vary with age and disease, and these factors should be considered in the restoration of facial features with prostheses using elastomeric materials. The objective of inventing SY blending elastomers is to provide prostheses that are hard and rigid where the facial features are hard and rigid, and soft and flexible where the facial structures are soft and movable, thus fitting the prostheses to anatomic and functional requirements of the patient.

When the materials were compared, MDX-4-4210 ($\bar{X}$ 37.0) had the highest Shore-A hardness, it could be used in auricle and nose as bracket structure. Usually, the softer materials more closely approximate the physical characteristics of the skin. The hardness of SY-28 silicone elastomer was 28.0, and suitable for ideal prosthetic materials in ear and nose defects. The hardness of SY-20 silicone elastomer was 20.0, and it possessed soft and pliable enough to adapt to rehabilitation of facial softer tissue. They seem better to simulate the characteristics of the facial tissues than previously used materials.

Compound silicone elastomer mixed by two components formed two phase in microstructure. According to continuity of phase, compound silicone elastomer could be classified three types: (1) equable phase structure; (2) single-phase continuous structure; (3) dual-phase continuous structure. SY-28 silicone elastomer was combined A component with B component. The ratio of A to B was 79: 21. The study indicates that when one component account for more 74% of total, it appeared continuous phase. Usually, continuous phase indicated basic property of the mixture, especially in mechanical properties. Because A component account for 79% of SY-28 silicone elastomer, it had excellent mechanical properties. B component had higher ultimate elongation and tear strength, which commutative strengthen mechanical properties of the mixture. So SY-28 silicone elastomer was superior to MDX－4-4210 in ultimate elongation and tear strength, which assured it possess enough flexibility capacity to accommodate the facial movements.

SY-20 silicone elastomer was combined A component with C component. The ratio of A to C was 78: 22. A component account for more 78% of total, it appeared continuous phase which assured SY-20 silicone elastomer had excellent mechanical properties. Because C component had lower hardness, relatively decreased hardness of the mixture, SY-20 silicone elastomer had soft and pliable enough to adapt to rehabilitation of facial softer tissue.

CONCLUSION

From the preliminary results obtained, it is reasonable to postulate the various compositions of silicone elastomers that are capable of yielding the mechanical properties for the prostheses that are desired and needed. Results showed that the physical and mechanical behavior of the silicone elastomers can be altered by variations in the basic composition of the material accomplished through changes in the ratio component. Based on the present study, it appears that SY-28 and SY-20 silicone elastomers are suitable for use in fabricating of clinical prostheses.

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