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Original Research

A Comparative Study on the Efficiency of Pigmented and non Pigmented Elastomeric Chains Using Differential Scanning Calorimetry

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ABSTRACT:

Orthodontic treatment involves the use of force delivery systems such as arch wires and elastomeric chains. Their mechanical property varies among various manufacturers. It depends on their phase transformation temperature. Differential scanning calorimetry (DSC) is a method of thermal analysis which is extensively employed to assess the properties of orthodontic materials. In the field of orthodontics DSC is used to assess the phase transition temperature of orthodontic arch wires, glass transition temperature of polyurethane elastomers, and to evaluate the degree of cure of dental resins. The present study highlights the clinical application of differential scanning calorimetry in evaluating the Glass transition temperature of polyurethane elastomeric chains.

Key words: ***Differential scanning calorimetry (DSC), Glass transition temperature (Tg)***

INTRODUCTION

Current advances in analytical instrumentation offer powerful tool for the study of orthodontic biomaterials and for characterization of its molecular structure, composition and properties. Thermal analysis of materials is one such technique used to have an insight in to orthodontic materials like polyurethane Elastomers, Superelastic NiTi wires and dental resins as a function of time and temperature.

Thermal Analysis include various methods

1. Thermo-gravimetric Analysis
2. Thermo-mechanical Analysis (Dialometry)
3. Differential thermal Analysis - DSC
4. Temperature modulated DSC

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Differential Scanning Calorimetry

The technique was developed by E.S.Watson and M.J. O'Neill in 1960. It was introduced commercially at Pittsburgh Conference on Analytical Chemistry and Applied Spectroscopy in 1963. The term DSC was coined to describe this instrument which measures energy directly and allows precise measurements of heat capacity. Differential scanning calorimetry is a thermal analysis technique which measures the energy absorbed or released associated with the transitions in molecular structure as a function of time or temperature.

Principle of DSC

DSC apparatus utilizes a sample pan which holds the sample and an empty reference pan. Each pan is placed on top of a heater in the DSC apparatus. At the start of testing, two pans are heated or cooled at a specific rate, usually 10°C per minute. The heating or cooling rate stays exactly the same throughout the experiment. As the temperature varies, a graph is plotted with the temperature on the X-axis and the difference in heat output of the two heaters on Y-axis (Fig: 1 and 2).

The underlying principle is that when the sample undergoes a physical transformation such as phase transitions, more or less heat will flow to it than the reference, to maintain both sample and reference at the same temperature depending on whether the process is exothermic or endothermic. By observing the difference in heat flow between the sample and reference, differential scanning calorimeters are able to measure the amount of heat absorbed or released during such transitions.

Differential Thermal Analysis (DTA)

An alternative technique, which shares much in common with DSC, is differential thermal analysis (DTA). In this technique, the heat flow to the sample and reference that remains the same rather than the temperature of the samples. When the sample and reference are heated identically phase changes and other thermal processes cause a difference in temperature between the sample and reference. Both DSC and DTA provide similar information. Many modern commercial DTA are called heat flux DSC. The technique is widely used across a range of applications, both as a routine quality test and as a research tool.

Uses of Differential scanning calorimetry (DSC)

1. DSC is used in the study of liquid crystals. As some forms of matter go from solid to liquid they go through a third state, which displays properties of both phases. This anisotropic liquid is known as a liquid crystalline or mesomorphous state. Using DSC, it is possible to observe the small energy changes that occur as matter transitions from a solid to a liquid crystal and from a liquid crystal to an isotropic liquid.
2. Used to assess the stability to oxidation of samples. Such analysis can be used to determine the stability and optimum storage conditions for a material or compound.
3. DSC makes a reasonable initial safety screening tool. DSC is widely used in the pharmaceutical and polymer industries. For the polymer chemist, DSC is a handy tool for studying curing processes, which allows the fine tuning of polymer properties. In the pharmaceutical industry it is necessary to have well-characterized drug compounds in order to define processing parameters.
4. In food science research, DSC is used in conjunction with other thermal analytical techniques to determine water dynamics. Changes in water distribution may be correlated with changes in texture. Similar to material science studies, the effects of curing on confectionery products can also be analyzed.

Applications of DSC in orthodontics

1. Glass transition temperature of polyurethane elastomeric chains.
2. Phase transition temperature of superelastic orthodontic arch wires.
3. Rate and degree of chemical cure of dental resins.

Importance of glass transition /Phase transition temperature

Orthodontic materials like superelastic orthodontic arch wires and polyurethane elastomers are manufactured by different companies using various methods and composition which determines the molecular structure and property of the material. DSC is used to evaluate the glass/phase transition temperature, the fundamental property which provides an insight in to the molecular architecture which points out to the overall clinical performance of the material. The study evaluates the glass transition temperature of pigmented and non pigmented polyurethane elastomeric chains from 3 different manufacturers.

GLASS TRANSITION TEMPERATURE OF POLYURETHENE ELASTOMERIC CHAINS

The range of temperature over which the solid polyurethane polymer transforms from a rigid glassy state to flexible rubbery state is known as the glass transition temperature which can be evaluated through DSC. Though many investigators evaluated the force delivery and force degradation of polyurethane polymers,[1,2] Michele R. Renick[3] was the pioneer worker who evaluated the Glass transition temperatures of pigmented elastomeric chains, the only study reported in the literature.

Polyurethane elastomeric chains or modules have been developed for orthodontic applications to close space and correct rotations.[4] Initially clear chains were introduced to satisfy the esthetic demands of the patient. Recent trends have been to market pigmented chains for younger orthodontic patients instead of clear ones. The question has arisen whether the variations in the manufacturing method and addition pigments have any influence on the clinical performance.

AIMS AND OBJECTIVES

The purpose of this study was to compare the Tg of pigmented and non-pigmented elastomeric chains obtained from 3 different manufacturers, within the same brand, in the as-received condition

MATERIALS AND METHODS

Elastomeric modules in spool chain form were obtained from 3 manufacturers (Table 1). Samples are placed in the aluminium pan and sealed. The sealed aluminium pan was placed in the cell of the DSC apparatus (Model No: Mettler DSC822, Fig 3). An empty aluminium pan served as the inert control material. DSC test was performed by cooling the sample with liquid Nitrogen to a temperature of approximately -100°C and then heated at a rate of 10°C/min until the temperature reached room temperature. Glass transition temperature is recorded as DSC thermogram(Fig 4).

What does an increase or decrease in Tg suggest.

A higher glass transition temperature suggests a polymer in an earlier region of the rubbery plateau at room temperature. The higher value of Tg indicates a more rigid polymer. Greater the rigidity of the polymer more will be the force delivery of the material.

RESULT

The results are summarized in Table 2. There were no significant differences in Tg between pigmented and non pigmented within the 3M Unitek or Glenroe brands (Graph 1 &2). However within the Forestadent brand (Graph 3), there was greater variation in mean Tg for the 3 groups of pigmented chains (not exceeding 6°C). On comparison of the DSC measurements of clear chains for all 3 brands (Graph 4), Tg of the 3M Unitek brand were higher than the Tg of Glenroe and Forestadent.

DISCUSSION

On comparison of the results, the clear chains revealed a higher Tg indicating greater rigidity and better force delivery compared to pigmented ones. The result is in agreement to the findings of Michele R. Renick except for the differences were found in mean Tg for the pigmented chains of the Forestadent which were relatively small, that would probably cause a mild difference in their initial mechanical properties.

CONCLUSION

The study revealed the fact that addition of pigments to the polyurethane chains caused a remarkable change in the molecular configuration that resulted in the poor performance of the pigmented chains.

REFERENCES

1. David L. Baty, David J. Storie, and Joseph A. Von Fraunhofer Synthetic elastomeric chains: A literature review Am J Orthod Dentofacial Orthop 1994; Volume 105, Issue 6, 536 – 542)
2. David L. Baty, John E. Volz, and Joseph A. Von Fraunhofer Force delivery properties of colored elastomeric chains Am J Orthod Dentofacial Orthop 1994; Volume 106, Issue 1, 40-46.
3. Michele R. Renick, William A. Brantley, Michael Beck, Katherine W. L. Vig, and Chad S. Webb Studies of orthodontic elastomeric modules Part 1: Glass transition temperatures for representative pigmented products in the as received condition and after orthodontic use. Am J Orthod Dentofacial Orthop 2004; **126**: 337-343.
4. Rock W.P, H.J. Wilson D.Sc, C Chem, A laboratory investigation of orthodontic elastomeric chains, BJO 1985 Vol 12, (202-07).

Tables:

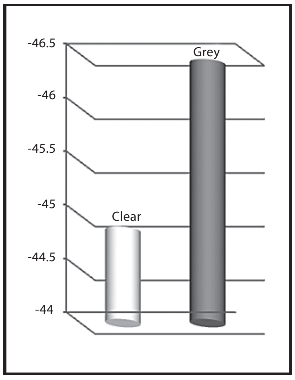
Brand	Colours Used		
3M Unitek	Clear	Grey	
Glenroe	Clear	Red	Blue
Forestadent	Clear	Red	Green

Table 1: Sample used for the study

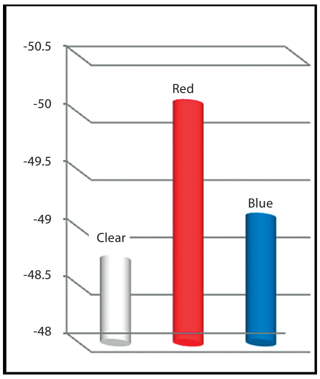
Nonpigmented	Pigmented					
3M Unitek	Clear	-44.53 °C	Gray	-46.41 °C		
Glenroe	Clear	-48.70 °C	Red	-50.09 °C	Blue	-49.10 °C
Forestadent	Clear	-46.63 °C	Red	-52.74 °C	Green	-49.77 °C

Table 2: Mean Tg of pigmented and non- pigmented chains of as-received samples.

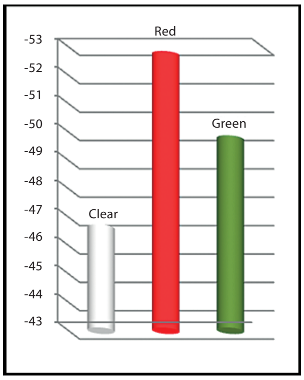
Graphs:



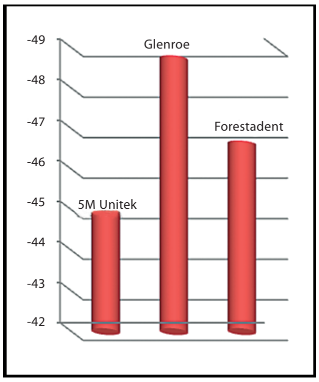
Graph 1: Comparison of Tg values of 3mUntitek samples



Graph 2: Comparison of Tg values of Glenroe samples



Graph 3: Comparison of Tg values of Forestadent samples



Graph 4: Comparison of Tg values of clear chains of 3 manufacturers

Figures:

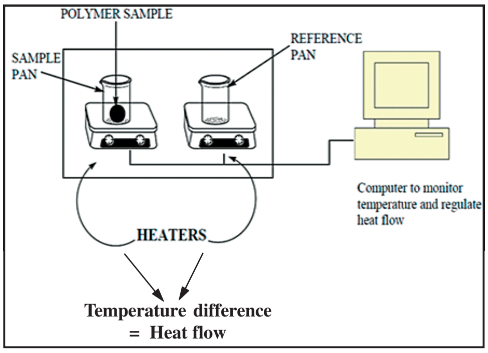


Figure 1: Principle of DSC - diagrammatic illustration

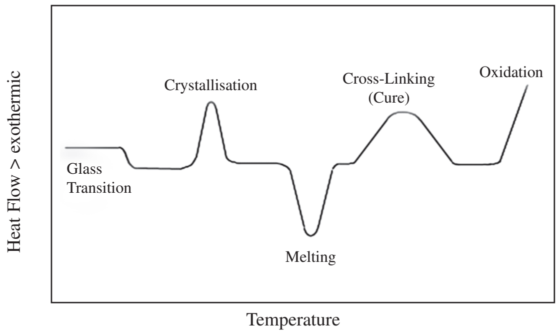


Figure 2: DSC Thermogram

Figure 3: DSC Apparatus

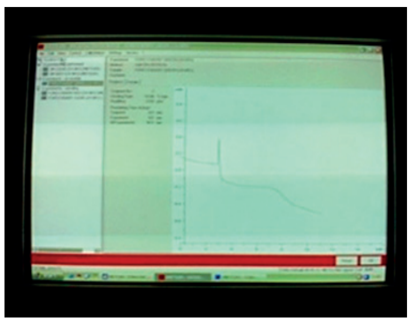


Figure 4: DSC Thermogram plotted on the computer screen