CHAPTER II

LITERATURE REVIEW

ORTHODONTIC ELASTOMERIC LIGATURES

The synthetic elastomeric ligatures are amorphous polymers made from polyurethanes (Wong, 1976; Young and Sandrik, 1979; Sims *et al.*, 1993; Taloumis *et al*, 1997; Terheyden *et al.*, 2000) whose exact composition is a commercial secret. These polyurethane materials have largely replaced natural latex rubbers with the reasons that the most significant limitation of natural latex is its enormous sensitivity to the effects of ozone or other free radical generating systems such as sunlight or ultraviolet light that produces cracks. The ozone breaks down the unsaturated double bonds at molecular level as the water molecule is absorbed. This weakens the latex polymers. The swelling and staining is due to the filling of the voids in the rubber matrix by fluids and bacteria debris (Wong, 1976).

The synthetic elastics that have been developed possess different chemical structures, but resemble natural rubber in many physical properties. The polyurethane elastic is a generic term given to the elastic polymers that contain the urethane linkage. They have been used for elastomeric ligatures. It has been found that they excel in strength and resistance to abrasion when compared with natural elastics. They tend to permanently distort, however, following long periods of time in the mouth and often lose their elastic properties (Wong, 1976; Young and Sandrik, 1979).

1. Basis of synthetic polymers

Basically, all polymers are formed by the creation of chemical linkages between relatively small molecules called "monomers", to form very large molecules called "polymers". The creation of chemical linkages between monomers to form polymers have different patterns: linear, branched and cross-linked. Thermoplastics are

formed by a flexible molecular structure, either linear or branched. Most linear polymers can be made to soften and take on new shapes by the application of heat and pressure. In other cases the chemical linkages of thermosetting plastics form a rigid, cross-linked molecule structure. Thus the three-dimensional network polymers are stable to heat and cannot be made to flow or melt (Richards *et al*, 1967; Harper, 1975; Billmeyer, 1984).

1.1 Molecular force and chemical bonding in polymers

The predominant bond in polymers is a covalent bond. Covalent bonding is one of the primary or inter-atomic bonds, which is formed when one or more pairs of valence electrons are shared between two atoms. There are forces acting between the molecules. They were generally known as secondary valence or intermolecular forces or van der Waals force. Their strengths are substantially less than that of the typical primary bond (Billmeyer, 1984).

The interactions between chains in many polymers are only van der Waals attraction. Though polymers do not generally crystallize, they often have regions in which polymer molecules are oriented to one another much as they would be in a crystal. Amorphous regions contain between polymer molecules with more random orientation. The balance between crystallites and amorphous regions has a significant influence on polymer properties. When the forces between chains in an amorphous polymer are weak, the chains are free to slip by one another. The polymer will have low tensile strength and be subjected to plastic flow (Richards *et al*, 1967).

1.2 The nature of elastomers

Polymers can be categorized by organized pattern into thermosetting materials and thermoplastic materials (Richards *et al*, 1967; Harper, 1975; Billmeyer, 1984). Nevertheless, elastomers are either thermoplastic or thermosetting, depending on their chemical nature as shown in Figure 2.1 (Harper, 1975).

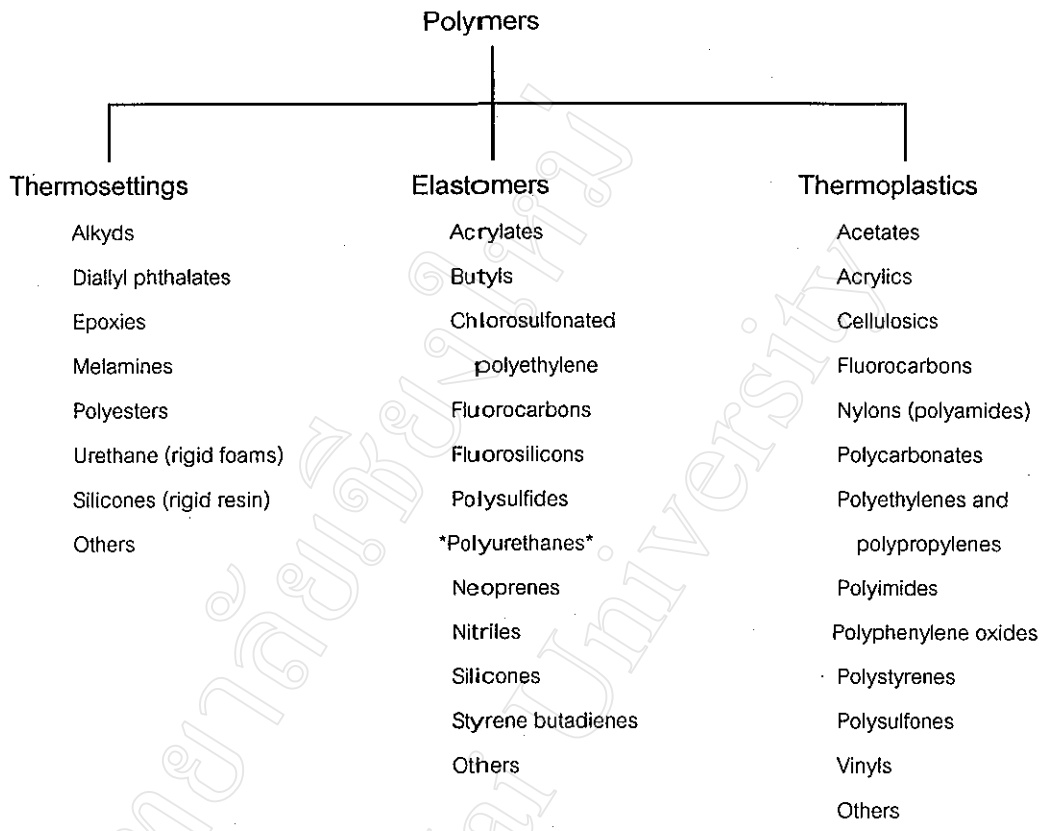

Figure 2.1 Diagram of polymers (Modified from Harper, 1975)

The term "elastomer" includes the complete spectrum of elastic or rubber-like polymers which are sometimes randomly referred to as rubbers, synthetic rubbers, or elastomers. More properly, however, rubber is a natural material and synthetic rubbers are polymers which have been synthesized to reproduce consistently the best properties of natural rubber (Harper, 1975).

Elastomers are intermediate in character between amorphous and crystalline polymers. When a polymer is largely amorphous with only weak forces between chains, elastic properties result. However, the presence of some crystallite region is necessary to prevent plastic flow. A judicious balancing of these two regions produces an elastomer. Cross-linking is also necessary to give elastomer structural stability, and non cross-linked elastomers usually show very pronounced cold flow and easily lose their shape (Richards *et al*, 1967).

2. Basic forms of elastomeric ligatures

The elastomeric ligatures have been used by orthodontists since 1960s and have become an integral part of many orthodontic practices. They can be manufactured in two basic forms:

1. Injection molded forms

The injection molded ligature is made by injection of liquefied elastomeric material into a mold and curing.

2. Cut forms

The cut ligature is sliced from previously processed elastomeric tubing.

The cut forms were more consistent in the amount of force produced than the injection molded forms (Hershey and Reynolds, 1975). However, most elastomeric ligatures are produced in injection molded form such as Power "O" s (Ormco corporation), Dentalastics® plastic ligature (Dentaurum), Elastic rings on modules (Leone), Mini-StiK™Patient Sticks, Quit-Stick™, Loose (3M Unitek), Uni Stick colored Ligatures, 6 Stick colored Ligatures (American Orthodontics), Dispense-A-Stix (TP Orthodontics, Inc) and Carousel Ring, Las-Tie (Tomy International Inc).

Recently, varieties of colored elastomeric ligatures have been introduced and have achieved notable popularity. In general, the colored ligatures behave similarly to the gray ligature in the same manufacture, but in some cases the coloring and filler materials used in tinting affects the forced delivery properties (Baty *et al.*, 1994).

3. Generated force and force decay patterns of elastomeric ligatures

The force generated by an elastomeric ligature depended on the magnitude of the initial force, the duration of force application, and the decay rate of the ligature (Taloumis *et al.*, 1997). Clinicians can control the magnitude of generated force with the selection of the appropriate sized ligature for the clinical situation and the duration of use. The magnitude of force is related to the elastomeric ligature dimension. Taloumis *et al.* (1997) evaluated the relationship between the force and the ligature dimension of gray molded elastomeric ligatures. They found a positive correlation between the wall

thickness and force, a negative correlation between the inside diameter and force, and a weak correlation between the outside diameter and force. It implied that the thicker the ligature and the smaller the inside diameter, the greater the force generated. But the outside diameter correlated poorly with the forces produced. They also suggested that the inside diameter of elastomeric ligature was a useful standard to assist clinicians in selecting elastomeric ligatures to use with a particular sized bracket for a desired orthodontic correction.

Many investigators reported permanent deformation and force decay pattern of elastomeric products. Elastomeric products lost 50% to 75% of their initial force within the first 24 hours of extension and were subsequently relatively stable (Andreasen and Bishara, 1970; Bishara and Andreasen, 1970; Hershey and Reynolds, 1975; Wong, 1976; Kovatch, 1976; Ash and Nikolai, 1978; Lu *et al.*, 1993).

A few studies investigated the behavior of single elastomeric ligatures. Taloumis *et al.* (1997) evaluated commercially available molded gray elastomeric ligatures from seven companies for force decay. They concluded that the greatest force loss occurred in the first 24 hours and the mean percentage of force loss for 24 hours was 53% to 68% for the seven companies tested. Samuels *et al.* (1993) studied the efficiency of space closure after premolar extraction by using an elastomeric module system, Alastik and wire ligature, (Unitek Corp., Monrovia, Calif.). These elastic modules were activated by stretching them by 2 to 3 millimeters (twice a the diameter), providing a starting force of 400 to 450 grams. The forces exerted after 5 to 8 weeks reduced to approximately zero.

4. Related environmental factors

Several investigators have attempted to determine the consequences of changing the environment with regard to the elastic behaviors of elastomeric materials. These attempts have looked at conditions that could exist within the oral cavity or might be used in disinfection or sterilization of the elastomeric materials before placement in the mouth.

Increasing temperature decreased the initial force and affected the mechanical properties of polyurethane elastomer (Brookes and Hershey, 1976; Stevenson and Robert, 1994). De Genova *et al.* (1985) reported that the elastomeric modules subjected to a thermal-cycled environment (between 15°C and 45°C) retained higher remaining force than did those held at a constant temperature of 37°C.

In addition, many investigators established that wetness (in saliva or water) decreased dimensional stability and initial force (Andreasen and Bishara, 1970; De Genova *et al.*, 1985; Huget, Patrick and Nunez, 1990). Huget, Patrick and Nunez (1990) also explained that exposure of these materials to water led first to weakening of noncovalent forces and then to degradation. von Fraunhofer, Coffelt and Orbell (1992) showed that exposure of elastomeric chains to artificial saliva and topical fluoride increased the distraction required to deliver force. Ferriter, Meyers and Lorton (1990) investigated the effect of pH extremes of plaque (pH 4.95) and saliva (pH 7.26) on elastomeric chains. They reported that a basic solution (pH 7.26) induced significantly greater force decay than an acidic solution (pH 4.95). Moreover, Jefferies and von Fraunhofer disinfected and sterilized elastomeric chain with 2% alkaline glutaraldehyde solution. They found a slight increase in the distraction required to generate 500 gm. of force for chains soaked for 1 week as compared with the controls. Normally, tooth moving forces are not within the 500 gm. range. Thus they concluded that 2% alkaline glutaraldehyde solution did not affect the properties of the chains and was effective and convenient to disinfect elastomeric chains.

Only Taloumis *et al.* (1997) studied the behavior of single elastomeric ligatures in a synthetic saliva bath at 37°C with pH 6.84. They concluded that moisture and heat had a pronounced effect on force decay and permanent deformation.

GLUTARALDEHYDE

Glutaraldehyde has been used as an antimicrobial agent for the past several decades. It was introduced as an efficient substitute for formaldehyde and became a disinfectant and a chemical sterilization solution in medical and dental practices.

1. Chemical nature and antimicrobial activity

Glutaraldehyde is a saturated 5-carbon dialdehyde with an empirical formula of $C_5H_8O_2$. The activity of glutaraldehyde is related to the reactivity of the aldehyde group which reacts with various enzymes and proteins. The degree of activity is usually associated with several variables, such as glutaraldehyde concentration at the time of use, presence of inorganic ions, dilution from using, and age of the solution. In addition, Scott and Gorman (1983) reported that the glutaraldehyde activity also depends on pH and temperature (Figure 2.2). Polymerization increases with a rise in pH and above pH 9 there is an extensive loss of aldehyde groups. Although acid glutaraldehyde is less markedly active than alkaline glutaraldehyde, this discrepancy disappears with increasing temperature. Increase in temperature produces more free aldehyde in acidic solution, but loss of reactive aldehyde group is possible in alkaline solution. Loss of reactive aldehyde groups also occurs with increased time. Glutaraldehyde is more stable at acidic than alkaline pH. Therefore, glutaraldehyde is usually obtained commercially as 2%, 25% or 50% solution of acidic pH, although for antimicrobial purposes a 2% solution is normally supplied, which must be made alkaline by addition of bicarbonate before use. In practice, glutaraldehyde is generally available as 2% solution to which an "activator" is added to bring the pH to approximately 8 before use.

Glutaraldehyde has a broad spectrum of activity and rapid rate of kill. It is active against vegetative bacteria including their resistant spores, mycelial and spore forms of fungi and various types of viruses. Glutaraldehyde destroys microorganisms by interfering with enzymatic activity, and with synthesis and function of the nucleic acids, which are essential for cell survival (Hugo and Russell, 1982; Scott and Gorman, 1983; Cottone and Molinari, 1996).

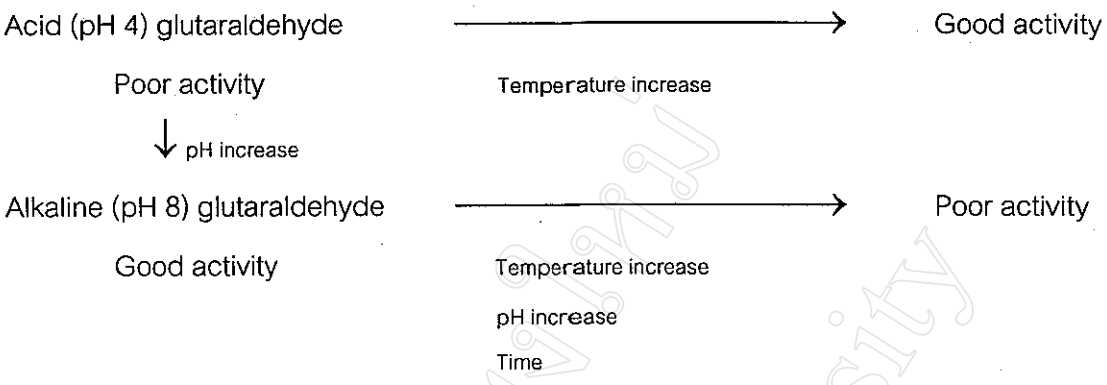

Figure 2.2 Influence of pH, temperature, and time on the activity of acid and alkaline glutaraldehyde solutions (Scott and Gorman, 1983)

2. Applications and toxicology

Glutaraldehyde is used extensively in several major nonmicrobiologic areas including the leather tanning industry and in the tissue fixation for electron microscopy. In a microbiologic context, glutaraldehyde has been recommended for the liquid chemical disinfection/sterilization of medical and dental materials that cannot be exposed to heat. The main advantages of glutaraldehyde are as follows (Hugo and Russell, 1982; Scott and Gorman, 1983):

1) it has a broad spectrum of activity, a rapid microbicidal action, and an effective sporicidal activity,

2) it is active in the presence of organic matter,

3) it is non-corrosive to metals, rubber, and most materials.

There are several available commercial glutaraldehyde solutions, varying according to preservatives added and pH levels. Acidic solutions have a pH level of 4.5 to 6.5, neutral solutions maintain a pH of 6.5 to 7.5, and an alkaline pH ranges from 7.5 to 8.5. Various kinds of glutaraldehyde products with their chemical classifications and properties are shown in Table 2.1.

Table 2.1 Products of glutaraldehyde (GTH). (Modified from Council on Dental Therapeutics, 1985)

GTH Products	Chemical Classification	Disinfectant	Sterilant
Banicide Sterall Wavicide-01	GTH, 2% acidic potentiated with nonionic ethoxylates of linear alcohols	Full strength, 10 minutes at room temperature	Full strength, 1 hour at 60°C, or 4 hours at 40°C-50°C, or 10 hours at room temperature
Cidex-7 ProCide-28 Centra-28 Omnicide Pose-Dex	GTH, 2% alkaline	Full strength, 10 minutes at room temperature	Full strength, 10 hours at room temperature
Sporicidin	GTH, 2% alkaline with phenolic buffer	Diluted 1:16, 10 minutes at room temperature	Full strength, 6 3/4 hours at room temperature
Glutarex	GTH, 2% neutral	Full strength, 10 minutes at room temperature	Full strength, 10 minutes at room temperature

Glutaraldehyde is used extensively as antimicrobial agent in the disinfecting or sterilizing processes of the medical and dental materials. It is also hazardous to humans as follows (Scott and Gorman, 1983):

1) Brief skin contact may cause itching with mild to moderate local redness. Prolonged contact may result in staining of the skin. Repeated skin contact may cause a dermatitis.
2) Eye contact may cause conjunctivitis, seen as redness and swelling of the conjunctiva. Severe corneal injury may develop which could permanently impair vision if prompt first aid and medical treatment are not obtained. Vapour may

cause stinging sensations in the eye with excess tear production, blinking and possibly a slight redness of the conjunctiva.

3) Inhalation of vapour irritates the respiratory tract, causing stinging sensations in the nose and throat. Inhalation of vapour may cause asthma-like symptoms. Heating the solution may result in more severe irritant effects.

4) Ingestion may result in mild to moderate irritation or chemical burns of the mouth, throat, oesophagus and stomach. There may be discomfort or pain in the mouth and throat, nausea, vomiting and diarrhea.

The user must adhere to the directions of use. Following immersion in glutaraldehyde solution, thoroughly rinse the medical device or material with the appropriated quality of water at least 1 minute and do not reuse the water for rinsing or any other purpose as it will be contaminated with glutaraldehyde.