CHAPTER V
DISCUSSION

The discussion was presented as follows:

I. Comparison of the initial dimensions and initial force among 1, 2, 3-time glutaraldehyde treated and untreated elastomeric ligatures.

II. Comparison of the percentage of remaining force at each time interval among 1, 2, 3-time glutaraldehyde treated and untreated elastomeric ligatures.

III. Comparison of the percentage of remaining force among seven time intervals to 28 days of 1, 2, 3-time glutaraldehyde treated and untreated elastomeric ligatures.

I. Comparison of the initial dimensions and initial force among 1, 2, 3-time glutaraldehyde treated and untreated elastomeric ligatures

The initial overall shape of four groups of elastomeric ligatures (1, 2, 3-time glutaraldehyde treated and untreated ligatures) were relatively similar but the outside diameter (OD) and wall thickness (WT) of treated ligatures were larger than those of untreated ligatures (Table 4.1). Among OD, ID and WT, the inside diameter (ID) showed the least change, which was not significantly different among the four groups (Table 4.2). The inside area might have more cross-linked molecular pattern than the outside area. However, the inside diameter of ligatures had a tendency to decrease when exposed to a 2% glutaraldehyde solution. Dimensional changes in treated ligatures was certainly one of the causes of fluid or moisture absorption. Young and Sandrik (1979) explained that polymers such as elastomeric materials were relatively unaffected by short exposures to water, but decomposed under prolonged contact with water, dilute acids or moist heat. These factors also caused swelling and slow hydrolysis.

Two percent glutaraldehyde solution deleterious affected not only the dimensional stability of elastomeric ligatures, but also their initial generated force. Table 4.5 showed that the initial force of group I (635.47 grams) was higher than that of group II (631.63 grams) and group III (601.40 grams), and the initial force of group IV (595.73 grams) was the lowest ($F_{0\,I} > F_{0\,II} > F_{0\,III} > F_{0\,IV}$). It implied that the more the number of immersions, the lower the force generated. It also indicated that immersing elastomeric ligatures in a 2% glutaraldehyde solution decreased their initial force. The results of this study supported the findings of many investigators (Andreasen and Bishara, 1970; De Genova *et al.*, 1985; Huget, Patrick and Nunez, 1990) that wetness decreased dimensional stability and initial force. Huget, Patrick and Nunez (1990) suggested that ligatures exposed to moisture showed weakening of noncovalent forces and then degradation. Nikolai (1985) found that molecular solids such as elastics may be increasingly vulnerable to chemical degradation in a moist environment. Wong (1976) and Kiliany (1985) explained that heat and chemical factors such as water, saliva and compounds which generated free radicals, could accelerate the breakage of the molecular cross-links of polyurethane polyesters, and lead to rapid relaxation of elastomeic materials.

Although a 2% glutaraldehyde solution had adverse effects on the initial dimensions and initial force of elastomeric ligatures, neither the initial dimensions nor the initial force of group II differed statistically significantly from those of group I (Tables 4.2, 4.3, 4.4 and 4.7). This indicated that the one time immersion in a 2% glutaraldehyde solution had no significantly deleterious effect on the initial dimension and force of elastomeric ligatures.

The initial force of group III (601.40 grams) and IV (595.73 grams) was significantly lower than that of group I (635.47 grams). When the initial force of group III and IV was compared with that of group I, it was 94.64% and 95.75% of it. Even though immersion in a 2% glutaraldehyde solution 2 or 3 times caused a statistically significant degradation in the initial force of elastomeric ligatures, the force reduction following glutaraldehyde treatment did not exceed 7% of the initial force of untreated ligatures. These changes were relatively small and not clinically critical when compared with the usual force loss of 53%-68% of elastic relaxation within the first 24 hours (Taloumis *et al.*, 1997).

II. Comparison of the percentage of remaining force at each time interval among 1, 2, 3-time glutaraldehyde treated and untreated elastomeric ligatures

The generated force of subgroup 2 to subgroup 7 in each group represented the remaining force at the 1^{st}, 2^{nd}, 7^{th}, 14^{th}, 21^{st} and 28^{th}days respectively. They were transferred to percentages of their initial force because the generated force of each group was different; thus they were standardized to 100%. The initial force of all groups was one hundred percent. In Table 4.9, most of the PRF at each time interval among 1, 2, 3- time treated and untreated ligatures was insignificantly different (PRF_1, PRF_7, PRF_{14}, PRF_{21}) whereas their initial force was significantly different (Table 4.6). The PRF and force decay characteristics were not related to the magnitude of the initial force. This result agreed with that of Hershey and Reynold (1975). They reported that force decay and the PRF were not related to the amount of initial force. However, this contrasted with the findings of Young and Sandrik (1979) and Lu *et al* (1993). They indicated that the higher the initial force, the higher the force decay, as well as the lower the PRF. Nevertheless, the studies as mentioned above investigated elastomeric chains and latex rubber. There was no study investigating the relationships among the initial force, force decay and PRF of single elastomeric ligatures.

However, the PRF_2 and PRF_{28} showed highly significant differences among four groups. The PRF_2 of group II was significantly lower than that of group I and IV. The PRF_{28} of group III was significantly higher than that of group I, II and IV. This might result from errors of testing of the remaining force at the 2nd day and 28th day.

III. Comparison of the percentage of remaining force among six time intervals of 1, 2, 3-time glutaraldehyde treated and untreated elastomeric ligatures

The pattern of PRF of untreated elastomeric ligatures (group I) throughout 28 days as in Figure 4.2 showed that the generated force continuously decreased with time. The greatest force loss occurred on the first 24 hours and then it gradually decreased throughout 28 day-period as did the force decay pattern of elastomeric ligatures in the study of Taloumis *et al* (1997). However, the values of the initial force, remaining force and percentage of remaining force were different because the research designs and experimental conditions such as temperature, pH, humidity were not the same. In addition, the pattern of PRF of elastomeric ligatures in this investigation was also similar to that of elastomeric material as in the studies of Andreasen and Bishara (1970), Bishara and Andreasen (1970), Hershey and Reynolds (1975), Wong (1976), Kovatch (1976) and Ash (1977). Figure 4.2 also showed the patterns of the PRF of group II, III and IV (1, 2, 3-time glutaraldehyde treated elastomeric ligatures) compared to group I. The overall patterns were similar. The PRF of glutaraldehyde treated ligatures also decreased with time. However, they were slightly different. PRF after the

21st day of group I and II continuously decreased whereas those of group III and IV were constant (Tables 4.11, 4.12, 4.13 and 4.14).

The PRF at each time interval of all four groups was very low because the amount of the ligature stretched over the rectangular aluminium bar was rather large. Ligatures were stretched over the bar to simulate the stretch necessary for tying a ligature over not only an upper central incisor twin bracket (0.022 slot) but also an arch wire. In this experiment, the cross-section of the rectangular bar, 4 millimeters in width and 3 millimeters in height, was too large for the virtual stretching of a ligature over a bracket and an arch wire. In addition, putting elastomeric ligatures on the aluminium bar and taking them off certainly affected their generated force.

In the clinical study of Samuel *et al* (1993), the PRF of elastomeric ligatures used to close an extraction space dropped to approximately zero after 5 to 8 weeks. The ligatures was stretched 2 – 3 millimeters (twice of the diameter) to generate the initial force of 400 – 450 grams.

Elastomeric ligatures could be used in orthognathic surgery and maxillofacial trauma for immobilizing the mandible and maxilla. For intraoperative use, the sterile elastomeric ligatures were required. Terheyden *et al.* (2000) recommended that ethylene oxide was the material of choice for sterilizing polyurethane elastomeric ligatures for intraoperative mandibulomaxillary immobilization. Although sterilization with ethylene oxide was effective for heat-sensitive materials, it was a complicated and expensive method and was not practical in orthodontic clinics. Only disinfecting contaminated elastomeric ligatures was acceptable for routine orthodontic practices

The other disinfecting solutions which have usually been used in dental clinics such as povidone-iodine and isopropyl alcohol were not indicated for elastomeric ligatures because they were too aggressive to elastomeric ligatures (Scott and Gorman, 1983; Terheyden *et al*, 2000). Terheyden *et al* (2000) suggested that within the group of disinfecting solutions, glutaraldehyde solution was preferable for elastomeric ligatures.

The results in this study may help the orthodontists select appropriate ligatures for the right clinical situation. Elastomeric ligatures used to close space and tie the arch wire to the bracket required more consistent force. The untreated ligatures were recommended, otherwise the 1-time glutaraldehyde treated ligatures were acceptable. However, elastomeric ligatures were not recommended for the mechanics requiring complete bracket engagement such as during torquing or rotational correction because of their rapid force loss in the first day. They were suitable for use in the initial aligning and leveling phase of orthodontics (Taloumis *et al*, 1997; Faber, 2000).

Nevertheless, the 2 and 3-time glutaraldehyde treated ligatures seemed to be useful when the force level was not considered, such as in the case of the minor rotational correction by applying a ligature on the attachments as rotational and anti-rotational force.

Elastomeric ligature products were generally available in sealed plastic packages, but they were not disinfected or sterilized. In cases when additional prevention was desired, the ligatures might be disinfected with a 2% glutaraldehyde solution before use.

In practice, an entire stick of elastomeric ligatures was frequently not used at once and some orthodontists would rather throw away the remaining ligatures than disinfect them for other patients, with the reason that the disinfection procedure was rather a difficult and complicated task and may be more costly. However, many orthodontic clinics use a cold sterilization, particularly a 2% glutaraldehyde solution, to disinfect the orthodontic pliers and other instruments. In this case, using a 2% glutaraldehyde solution for disinfection of the contaminated remaining elastomeric ligatures as well as the orthodontic instruments, gives the most cost-benefit. A stick of elastomeric ligatures should be divided into small units.

The results of this investigation suggested that a 2% glutaraldehyde solution was suitable for disinfecting elastomeric ligatures because it had no markedly deteriorating effects on their dimensions and generated force. Moreover, chemical disinfectant, especially a 2% glutaraldehyde solution, is practical for orthodontic clinics.

Limitations of this investigation

1. There were a large number of samples tested in seven time intervals (210 samples in each time interval). A sample testing took more than one minute and each group testing took about 70 minutes. The remaining force of all samples was tested in order of group, from group I to group IV; thus the samples of group IV had more stretching time on the rectangular bar than groups III, II and I. This time differentiation resulted in a generated force in group IV which was relatively low when compared to other groups.

2. Samples could be tested for the generated force only one time because of their elastic properties. The sample tested for the initial force could not be repeatedly tested for the remaining force at the following time intervals. Therefore, the generated force of subgroup 2 to subgroup 7 replaced the remaining force at the 1^{st}, 2^{nd}, 7^{th}, 14^{th}, 21^{st} and 28^{th} days respectively.

3. The dimension-measuring instrument, a ten-times magnifying glass with scale (SKS10XSD, Japan), could measure only to the nearest of 0.1 millimeter.

4. The final dimensions of elastomeric ligatures could not be measured because they had permanent deformation.

5. The elastomeric ligatures were bought from local vendors; their shelf-life and properties may have been affected by environment and time.

6. This experiment could not perfectly simulate such aspects of the oral environment as thermal cycling, pH level, saliva etc.

Suggestions for further study

1. The actually load cell of the universal testing machine in tension tests should be smaller than 100 newtons for more sensitivity.

2. Since the greatest force loss of elastomeric ligatures occurred on the first 24 hours, the remaining force at the 1^{st} and 2^{nd} hours should be tested.

3. Dimension-measuring instruments should have more sensitivity.

4. The aluminium bars should have rounder angles and shorter length to reduce damage to elastomeric ligatures.

5. For the best results in clinical application, the effectiveness of a 2% glutaraldehyde solution in destroying microorganisms should be tested when used according to company directions.