CHAPTER IV

RESULTS

The results of this experiment was separated in two parts:

Part I: Elastic limit of orthodontic elastomeric chains

1.1 Force-displacement curves of three-loop and four-loop of closed, open and wide space orthodontic elastomeric chains,

1.2 Means and standard deviations of generated force, displacement and percent elongation at elastic limit of three-loop and four-loop of three forms of orthodontic elastomeric chains,

1.3 Two-way analysis of variance of generated force and percent elongation at elastic limit among three-loop and four-loop groups of three forms of orthodontic elastomeric chains, and

1.4 Multiple comparisons of generated force and percent elongation at elastic limit among three-loop and four-loop groups of three forms of orthodontic elastomeric chains.

Part II: Force decay of orthodontic elastomeric chains in the simulated tooth movement condition

2.1 Means and standard deviations of remaining force and percent remaining force in eight periods of three forms of orthodontic elastomeric chains and their force relaxation patterns during six-week period,

2.2 One-way analysis of variance and multiple comparisons of percent remaining force among three forms of orthodontic elastomeric chains in each period and among eight periods in the same form of elastomeric chains,

2.3 Means and standard deviations of force decay, percent force decay, force decay rate and percent force decay rate at each time interval and the

force decay pattern of three forms of orthodontic elastomeric chains during six-week period,

2.4 One-way analysis of variance and multiple comparisons of percent force decay rate among three forms of orthodontic elastomeric chains in each time interval, and among seven time intervals in the same form of elastomeric chains.

PART I: ELASTIC LIMIT OF ORTHODONTIC ELASTOMERIC CHAINS

Six groups of three-loop and four-loop closed, open and wide space orthodontic elastomeric chains were measured their original chain length and tested in tension up to 10-newton force for investigating the force-displacement curves, the generated force, displacement and percent elongation at elastic limit.

1.1 Force-displacement curves of three-loop and four-loop closed, open and wide space of orthodontic elastomeric chains

The force-displacement curves of six groups of orthodontic elastomeric chains differed slightly, but the overall shape were relatively similar. Each curve was divided in three parts: initial, middle and final parts (Figure 4.1). The force-displacement curves of six groups (C_3, C_4, O_3, O_4, W_3 and W_4) were shown in Figure 4.2 - 4.7 respectively.

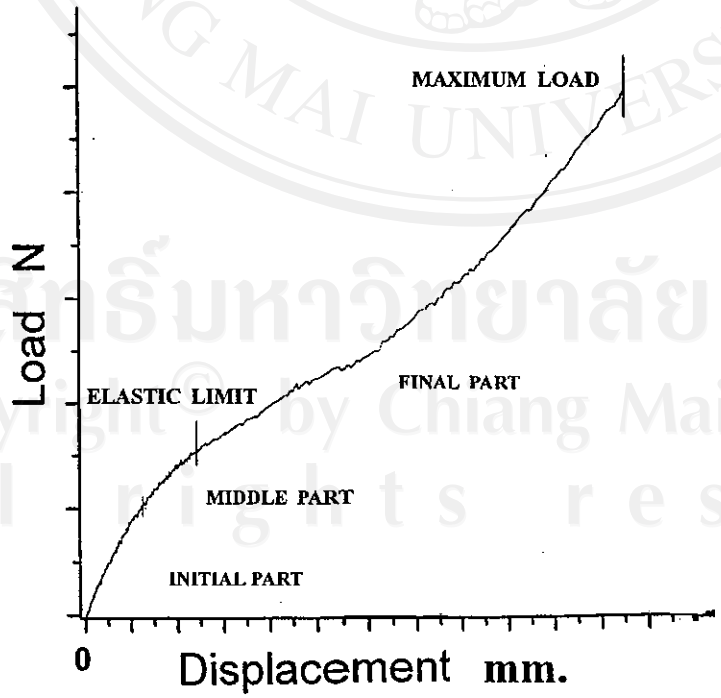

Figure 4.1 Three parts of the force-displacement curve of elastomeric chain

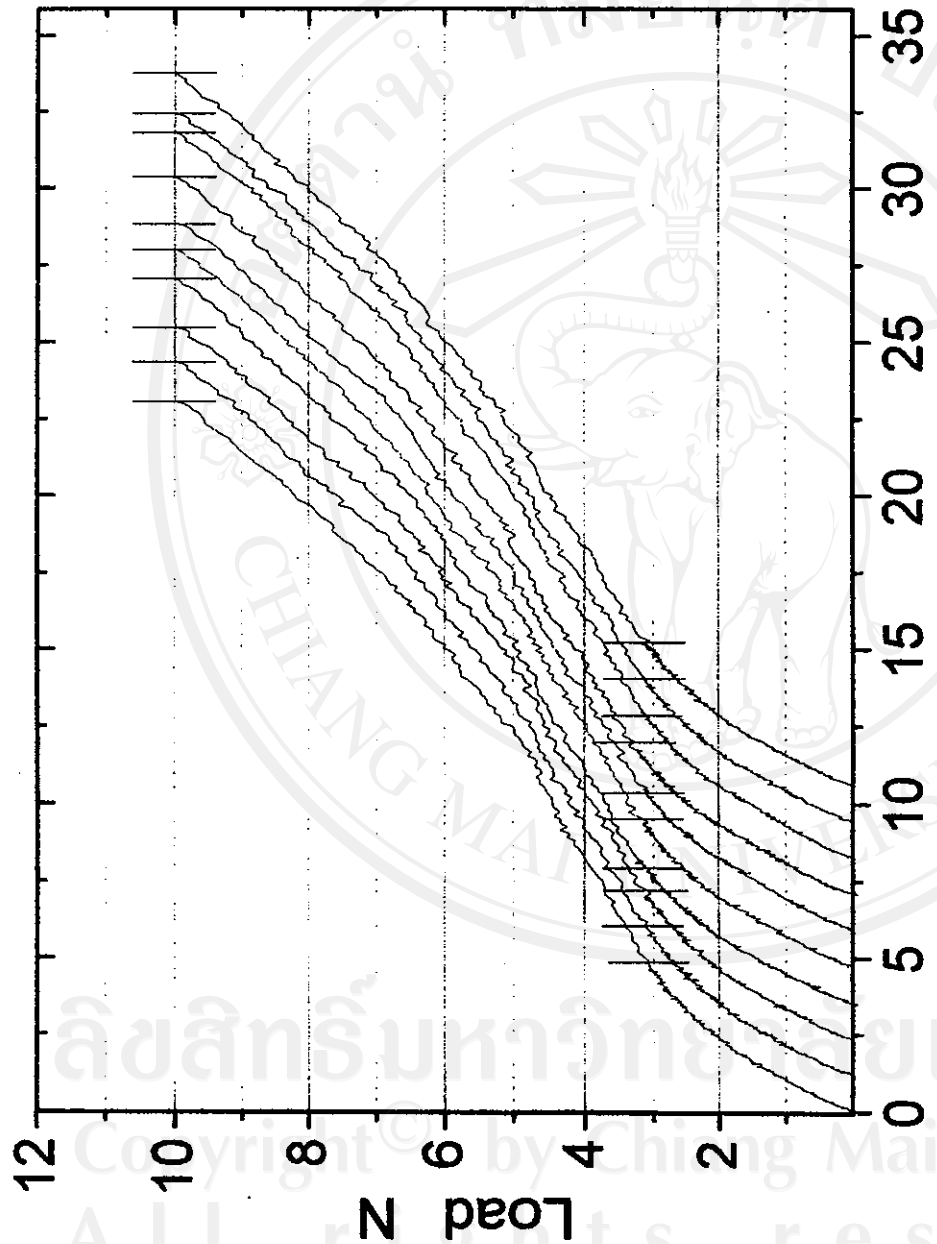

Figure 4.2 Ten samples of force-displacement curves with the elastic limit points of three-loop closed elastomeric chains (C_3)

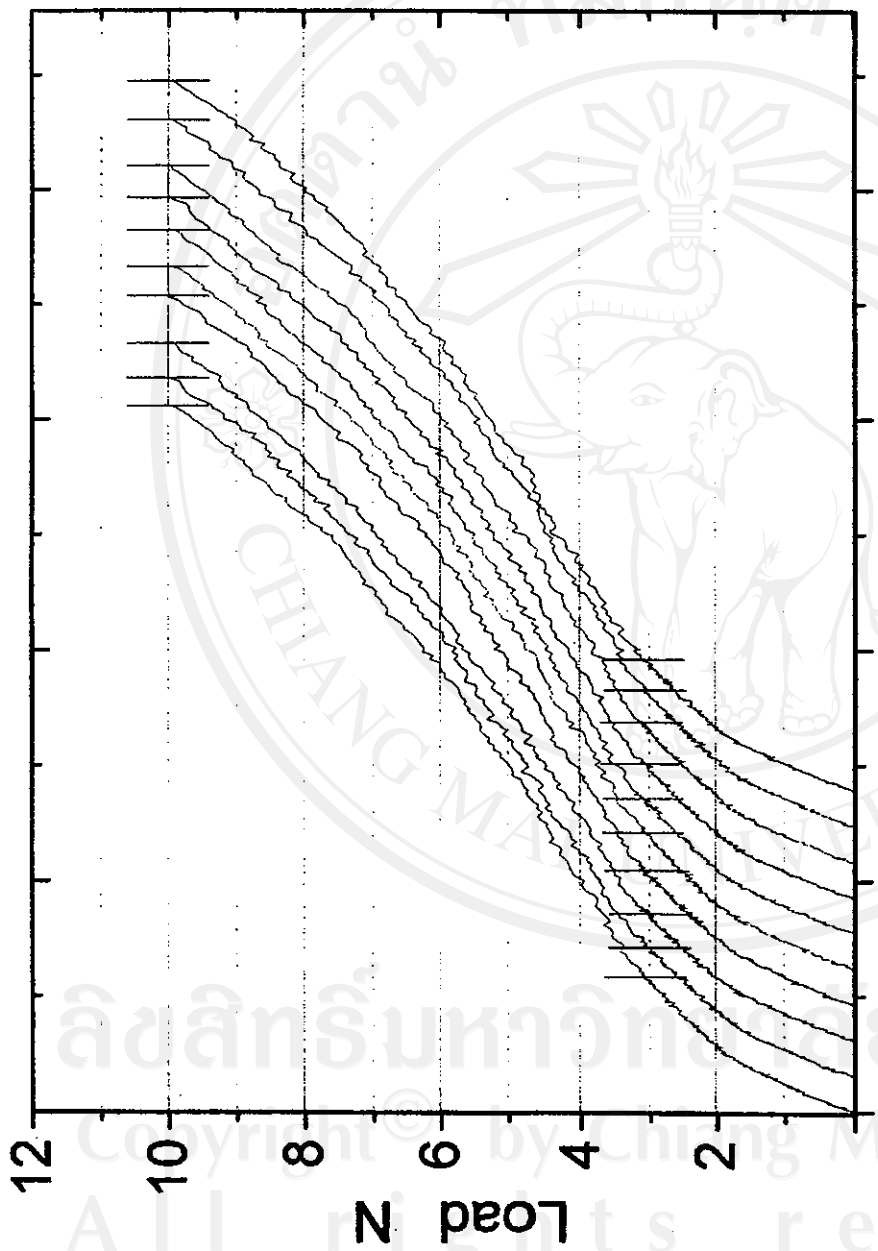

Figure 4.3 Ten samples of force-displacement curves with the elastic limit points of four-loop closed elastomeric chains (C_4)

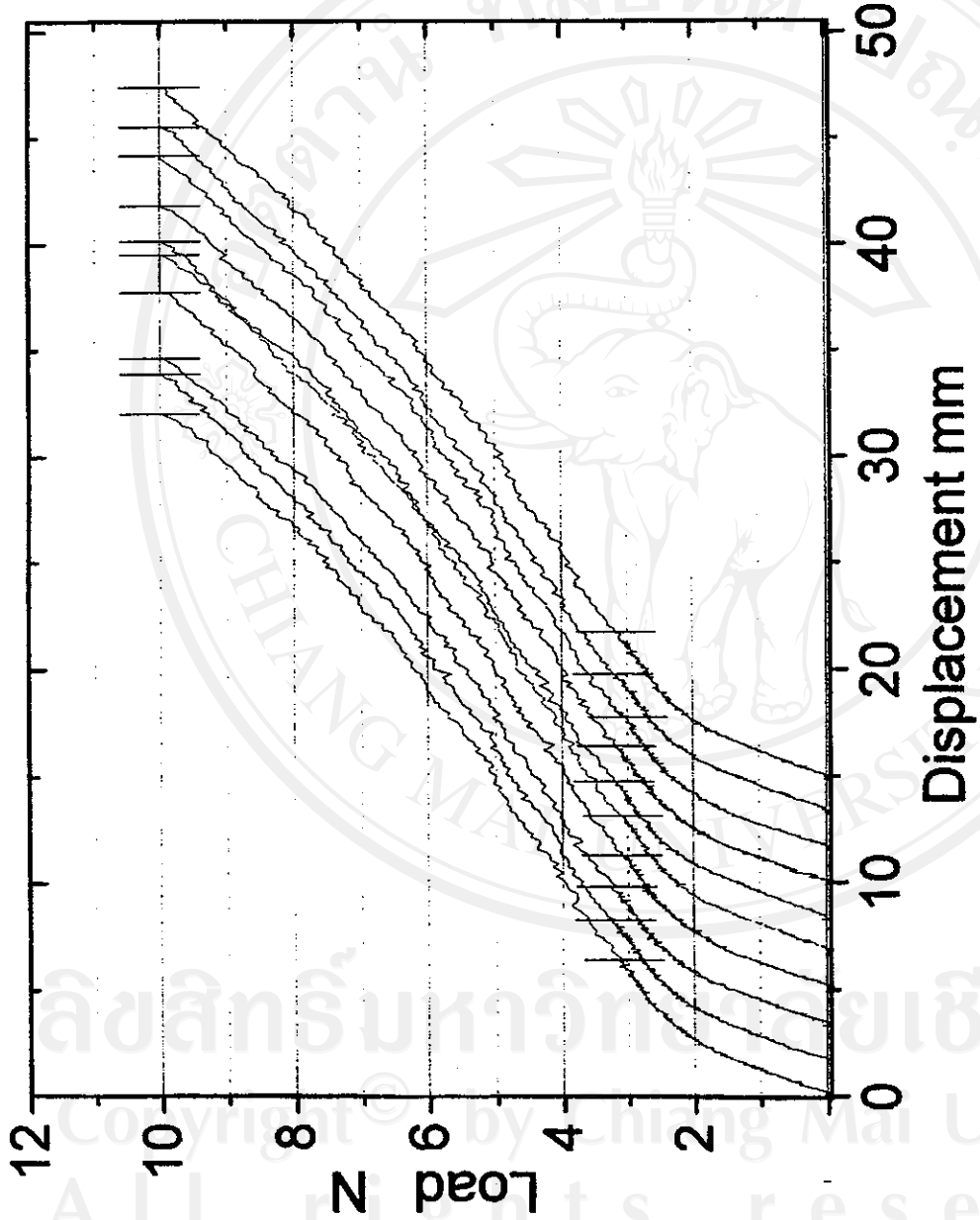

Figure 4.4 Ten samples of force-displacement curves with the elastic limit points of three-loop open elastomeric chains (O_3)

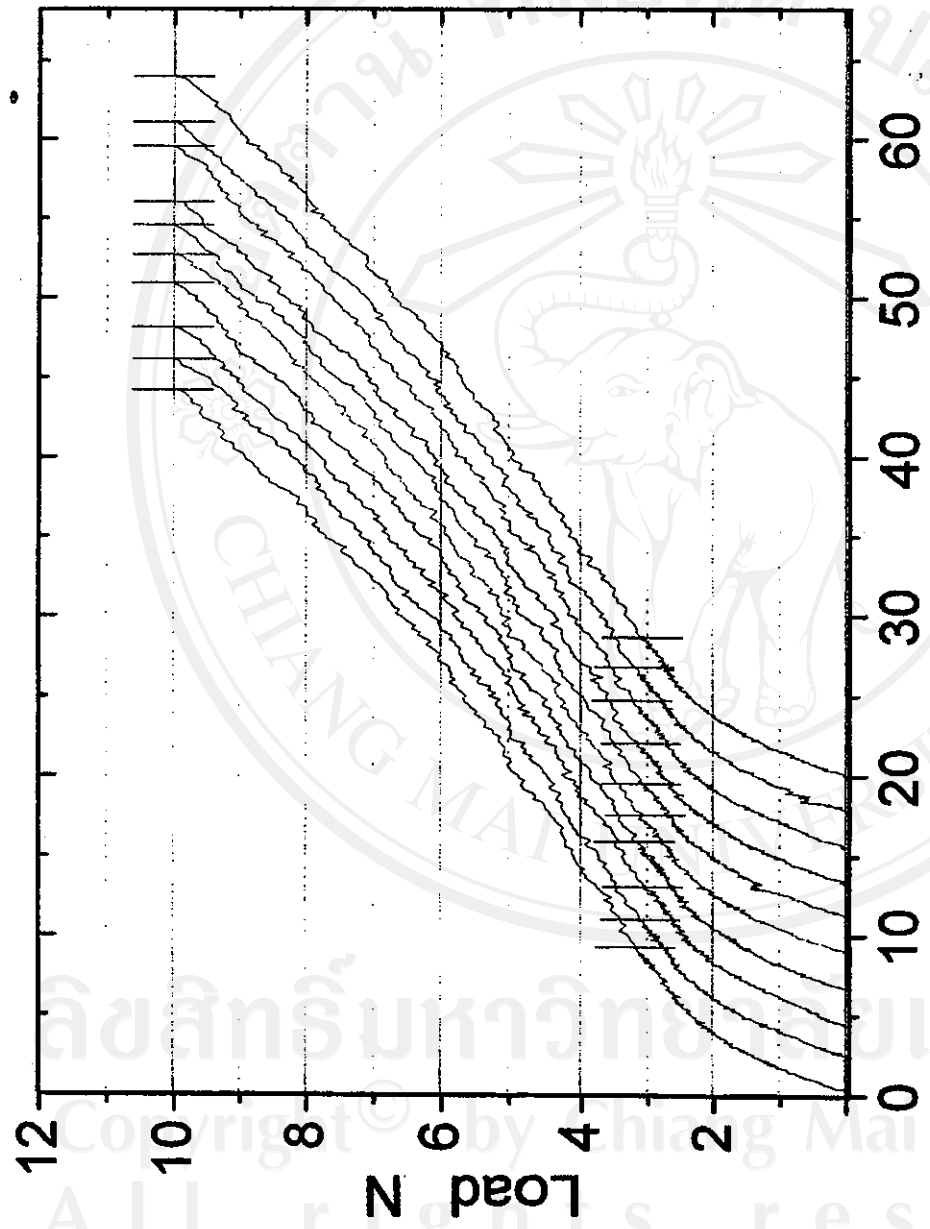

Figure 4.5 Ten samples of force-displacement curves with the elastic limit points of four-loop open elastomeric chains (O_4)

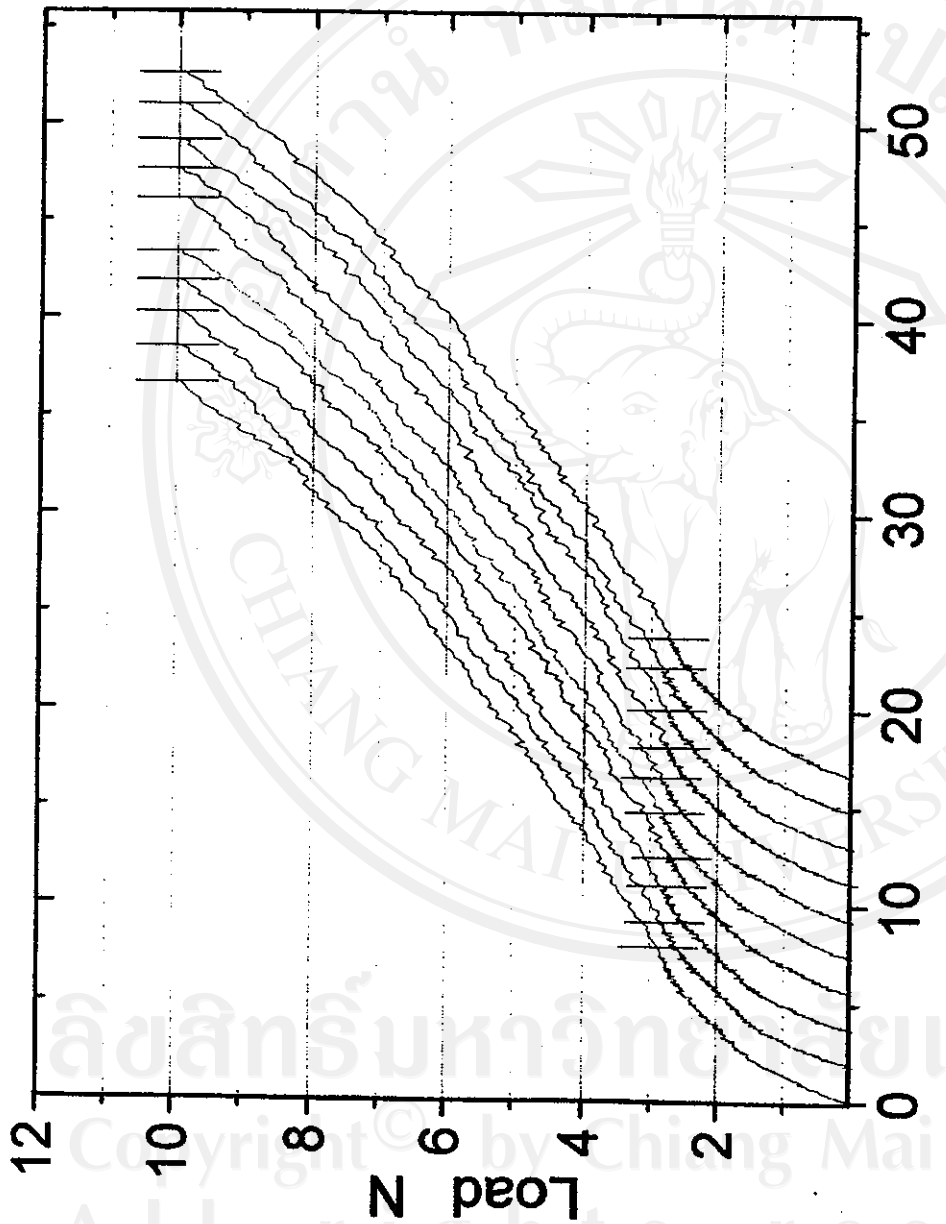

Figure 4.6 Ten samples of force-displacement curves with the elastic limit points of three-loop wide elastomeric chains (W_3)

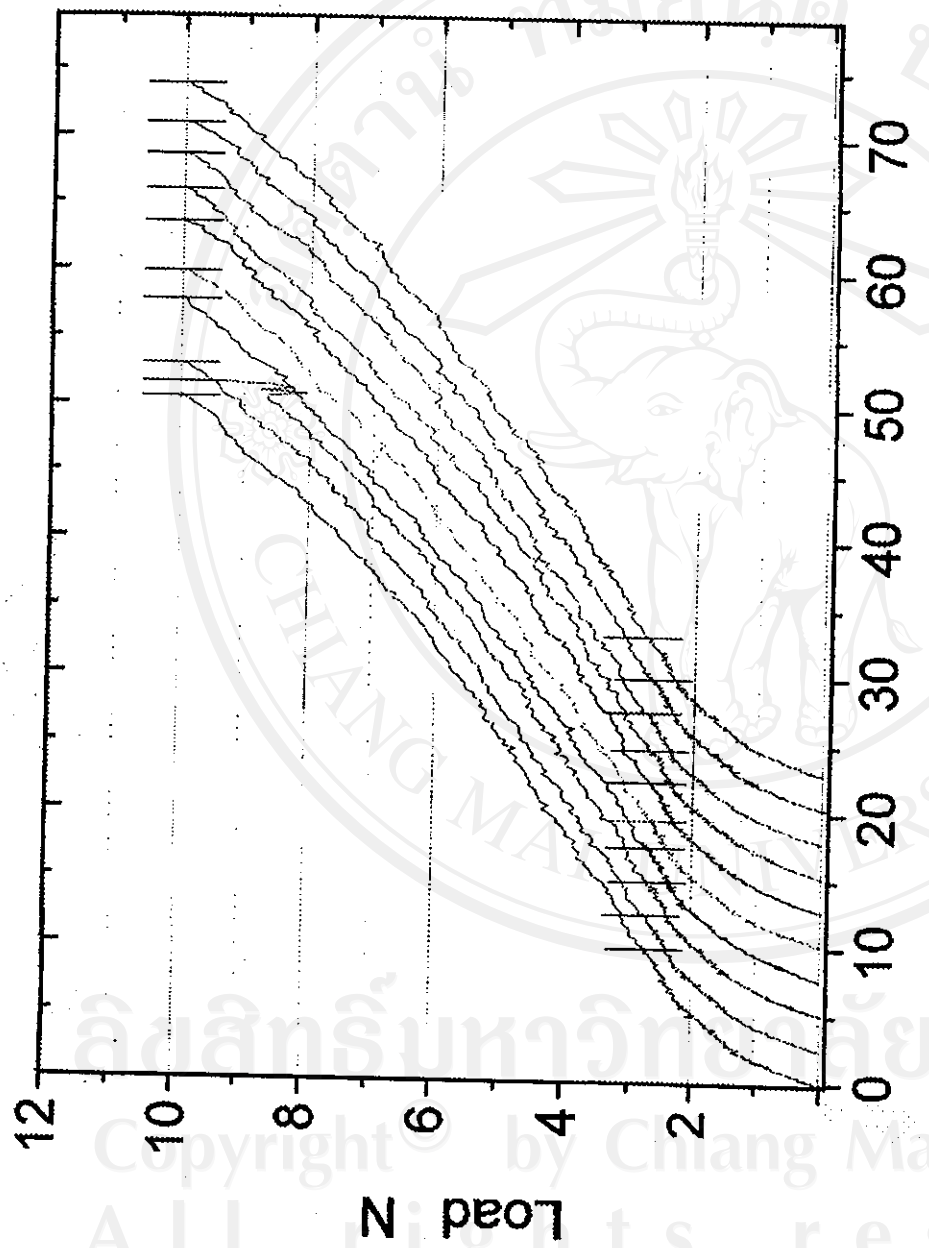

Figure 4.7 Ten samples of force-displacement curves with the elastic limit points of four-loop wide elastomeric chains (W_4)

From Figure 4.2 - 4.7, the initial part of all force-displacement curves, were almost linear with slightly curve at the beginning. They had short steady, continuous and high frequency traced lines. They were represented the generated force from 0 newton to 2 newtons (200 grams) in closed and open groups and 1.5 newtons (150 grams) in wide group. It refered that the elastomeric chain, which was stretched under its elastic limit generated high frequency continuous increasing force.

The middle part of tracings, following the initial part to the elastic limit point, were curved with slightly decline and bolder than the initial part because they had larger range of force and were more unsteady. They also had high frequency traced lines until the points that were marked as elastic limit, which were approximated 3 newtons (300 grams) in closed and open groups and slightly lower in wide group.

Beyond the elastic limit points were the final part of the curves, the tracings were thin and irregular with low frequency. They had low inclined curves at the beginning of part, and were steeper at the end part. The generated force from the over stretched its elastic limit was low frequency discrete increasing pattern.

At 10-newton force, the samples of six groups of elastomeric chains were sustained and all of them were not rupture. However, in either form of elastomeric chains the more extension exerted the more generated force. The slopes of force-displacement curves varied for each group, but their shapes were relatively similar.

1.2 Means and standard deviations of the generated force, displacement and percent elongation at elastic limit of three-loop and four-loop of three forms of orthodontic elastomeric chains

The generated force, displacement and percent elongation at elastic limit of six groups of elastomeric chains were obtained. The means and standard

deviations of the original chain length, generated force, displacement and percent elongation were shown in Table 4.1.

Table 4.1 Means and standard deviations of original chain length, force, displacement and percent elongation at elastic limit of six groups of elastomeric chains

Group	Org.length (mm.) $\bar{X} \pm SD$	Force (gm.) $\bar{X} \pm SD$	Displacement (mm.) $\bar{X} \pm SD$	Elongation (%) $\bar{X} \pm SD$
C_3	6.94 ± 0.03	317.74 ± 8.42	4.79 ± 0.24	68.94 ± 3.35
C_4	9.73 ± 0.03	314.24 ± 8.10	6.02 ± 0.26	61.86 ± 2.61
O_3	8.34 ± 0.08	313.81 ± 7.65	6.54 ± 0.19	78.41 ± 2.50
O_4	11.83 ± 0.08	312.52 ± 6.51	8.90 ± 0.29	75.26 ± 2.39
W_3	10.34 ± 0.04	278.30 ± 5.50	7.29 ± 0.26	70.48 ± 2.40
W_4	14.87 ± 0.08	273.38 ± 5.90	9.68 ± 0.27	65.10 ± 1.79

At elastic limit point, the generated force, displacement and percent elongation of six groups of elastomeric chain were different.

In the same number of loops, the elastic strengths of the closed and open space groups were nearly the same, but they were greater than the wide space groups (C_3~O_3>W_3, C_4~O_4>W_4). In the same forms of elastomeric chains, the three-loop groups had greater elastic strengths than four-loop groups (C_3>C_4, O_3>O_4, W_3>W_4).

The displacements of wide groups were the greatest, but the least were in closed groups in both three-loop and four-loop groups (W_3>O_3>C_3, W_4>O_4>C_4). In the same forms of elastomeric chains, four-loop groups had greater displacement values than three-loop groups (C_4>C_3, O_4>O_3, W_4>W_3).

Furthermore, the open form had the highest percent elongation values, but the least were in the closed form in either three-loop and four-loop groups (O_3>W_3>C_3, O_4>W_4>C_4). Similary to elastic strength, the percent elongations of three-loop groups were higher than four-loop groups in all three forms (C_3>C_4, O_3>O_4, W_3>W_4).

In summary, among the same number of loops, the open form generated high force, the highest percent elongation and the moderate value of displacement. Closed from also generated high force, but it had the least displacement and percent elongation. The generated force of wide group especially W_4 was low, but its displacement was the highest with moderate percent elongation. In the same form of elastomeric chains, three-loop group established higher force and percent elongation, but lower displacement than four-loop group.

1.3 Two-way analysis of variance of generated force and percent elongation at elastic limit among three-loop and four-loop groups of three forms of orthodontic elastomeric chains

Two-way analysis of variance (ANOVA) was used to differentiate the generated force and percent elongation at elastic limit among three-loop and four-loop groups of three forms of elastomeric chains (Table 4.2).

Table 4.2 Two-way ANOVA of generated force and percent elongation at elastic limit of six groups of orthodontic elastomeric chains

Variables	F-value		
	Form	Number of loops	Form by Number of loops
Generated force	199.260***	3.118	0.322
Percent elongation	112.202***	6.665***	3.005

* $p< 0.05$, ** $p< 0.01$, *** $p< 0.001$

The generated forces at elastic limit of six groups of elastomeric chains were compared. There was significant difference by form ($p< 0.001$), but there was no significant difference by number of loops and also their interaction effects (form by number of loops).

Furthermore, there were significant differences in percent elongation by both form and number of loops ($p < 0.001$), but there was no significant difference by their interaction effects ($p < 0.05$).

In brief, the main effect of form influenced on both generated force and percent elongation, but the number of loops only effected on percent elongation.

1.4 Multiple comparisons of generated force and percent elongation at elastic limit among six groups of orthodontic elastomeric chains

Following two-way ANOVA showed significant differences, the multiple comparisons, Duncan's multiple range test, was used for comparing.

1.4.1 Multiple comparisons of generated force at elastic limit among six groups of orthodontic elastomeric chains

The comparisons of generated force among six groups of elastomeric chain were tested by Duncan's multiple range test, and illustrated in Table 4.3.

Table 4.3 Multiple comparisons of generated force at elastic limit of six groups of orthodontic elastomeric chains by Duncan's multiple range test

Groups	Closed 3	Closed 4	Open 3	Open 4	Wide 3	Wide 4
$\bar{X}$ (gm.)	317.74	314.24	313.81	312.52	278.30	273.38
Closed 3						
Closed 4	3.50					
Open 3	3.93	0.43				
Open 4	5.22	1.72	1.29			
Wide 3	39.44**	35.94**	35.51**	34.22**		
Wide 4	44.36**	40.86**	40.43**	39.14**	4.92	

* $p < 0.05$, ** $p < 0.01$

The generated forces of wide space groups (W_3, W_4) were significantly different ($p < 0.01$) from the closed and open space groups (C_3, C_4, O_3 and O_4).

1.4.2 Multiple comparisons of percent elongation at elastic limit among six groups of orthodontic elastomeric chains

The comparisons of percent elongation among six groups of elastomeric chains were tested by Duncan's multiple range test and illustrated in Table 4.4.

Table 4.4 Multiple comparisons of percent elongation at elastic limit of six groups of orthodontic elastomeric chains by Duncan's multiple range test

Groups	Closed 3	Closed 4	Open 3	Open 4	Wide 3	Wide 4
$\bar{X}$ (%)	68.94	61.86	78.41	75.26	70.48	65.10
Closed 3						
Closed 4	7.08**					
Open 3	9.47**	16.55**				
Open 4	6.32**	13.40**	3.15*			
Wide 3	1.54	8.62**	7.93**	4.78**		
Wide 4	3.84**	3.24*	13.31**	10.16**	5.38**	

* $p < 0.05$, ** $p < 0.01$

Most of the percent elongation at elastic limit were significantly different to each other in six groups of elastomeric chains ($p < 0.01$). The differences between O_3-O_4 and C_4-W_4 groups were also significant ($p < 0.05$), but there was no significant difference between C_3-W_3 ($p > 0.05$).

PART II: FORCE DECAY OF ORTHODONTIC ELASTOMERIC CHAINS IN THE SIMULATED TOOTH MOVEMENT CONDITION

All samples of three groups of elastomeric chainS (C_4, O_3 and W_3) were measured the initial force at 22.5 millimeters stretched and remeasured the force and the extended length after the first day, and weekly from the first to the sixth week with decreasing distance 0.5 millimeters per week. Table 4.5 showed the extended length, force, displacement and percent elongation of three forms of elastomeric chains in each time period through six weeks.

2.1 Means and standard deviations of remaining force and percent remaining force in eight periods of three forms of orthodontic elastomeric chains and their force relaxation patterns during six-week period

2.1.1 Means and standard deviations of remaining force and percent remaining force in eight periods of three forms of orthodontic elastomeric chains

The means and standard deviations of remaining force and percent remaining force of three forms of elastomeric chains in eight periods during six weeks with simulated tooth movement were shown in Table 4.6.

The remaining forces and percent remaining forces of all three forms of elastomeric chains were decreased continuously with time, but they dramatically dropped on the first day. Among three groups of elastomeric chains, C_4 produced high initial force (373.06 grams), and it maintained the highest remaining force (153.94 grams) and percent remaining force (41.27%) after six weeks. Although O_3 produced almost the same amount of initial force (375.09 grams) as C_4, but its remaining force (103.15 grams) and percent remaining force (27.51%) at the sixth week were lesser than C_4. The O_3 had greater initial force and remaining force, but it had lesser percent remaining force than W_3 (29.62%).

Table 4.5 Means and standard deviations of extended length, force, displacement and percent elongation of three forms of elastomeric chains in eight periods during six weeks

Time	Extended	Closed Form (C_4 /org.length 9.73 mm.)			Open Form (O_3 /org.length 8.34 mm.)			Wide Form (W_3 /org.length 10.34 mm.)		
	Length (mm.)	Force (gm.)	Displac.(mm.)	Elong.(%)	Force (gm.)	Displac.(mm.)	Elong.(%)	Force (gm.)	Displac.(mm.)	Elong.(%)
Initial	22.5	373.06 ± 4.85	12.77	131.24%	375.09 ± 5.38	14.16	169.78%	318.15 ± 4.17	12.16	117.60%
1st Day	22.5	257.18 ± 6.23	12.77	131.24%	226.25 ± 9.76	14.16	169.78%	203.80 ± 7.75	12.16	117.60%
1st Wk.	22.5	237.27 ± 6.06	12.77	131.24%	203.10 ± 6.96	14.16	169.78%	184.07 ± 7.49	12.16	117.60%
2nd Wk.	22.0	216.85 ± 5.83	12.27	126.10%	179.03 ± 6.67	13.66	163.79%	159.95 ± 3.36	11.66	112.76%
3rd Wk.	21.5	201.90 ± 4.55	11.77	120.97%	158.47 ± 5.83	13.16	157.79%	144.12 ± 4.69	11.16	107.93%
4th Wk	21.0	185.37 ± 4.81	11.27	115.83%	138.15 ± 5.26	12.66	151.80%	123.33 ± 2.64	10.66	103.09%
5th Wk.	20.5	169.58 ± 4.26	10.77	110.69%	121.11 ± 3.73	12.16	145.80%	109.12 ± 3.42	10.16	98.26%
6th Wk.	20.0	153.94 ± 3.14	10.27	105.55%	103.15 ± 4.03	11.66	139.81%	94.21 ± 4.42	9.66	93.42%

Table 4.6 Means and standard deviations of remaining force and percent remaining force in eight periods

Group / Time	Remaining force (gm.) and Percent remaining force (%)					
	Closed space (C_4)		Open space (O_3)		Wide space (W_3)	
	$\bar{X}$ ± SD (gm.)	$\bar{X}$ ± SD %	$\bar{X}$ ± SD (gm.)	$\bar{X}$ ± SD %	$\bar{X}$ ± SD (gm.)	$\bar{X}$ ± SD %
Initial	373.06±4.85	100.00±0.00	375.09±5.38	100.00±0.00	318.15±4.17	100.00±0.00
1st Day	257.18±6.23	68.95±1.86	226.25±9.76	60.32±2.55	203.80±7.75	64.06±2.29
1st Wk.	237.27±6.06	63.61±1.70	203.10±6.96	54.15±1.83	184.07±7.49	57.86±2.42
2nd Wk.	216.85±5.83	58.13±1.58	179.03±6.67	47.73±1.69	159.95±3.36	50.29±1.28
3rd Wk.	201.90±4.55	54.13±1.41	158.47±5.83	42.26±1.66	144.12±4.69	45.31±1.61
4th Wk.	185.37±4.81	49.70±1.56	138.15±5.26	36.84±1.51	123.33±2.64	38.77±0.86
5th Wk.	169.58±4.26	45.46±1.27	121.11±3.73	32.29±0.98	109.12±3.42	34.31±1.22
6th Wk.	153.94±3.14	41.27±1.03	103.15±4.03	27.51±1.15	94.21±4.42	29.62±1.39

2.1.2 Force relaxation pattern of the percent remaining force in eight periods of three forms of elastomeric chains

The patterns of percent remaining force of three forms of elastomeric chains were relatively similar. The declinations of the percent remaining force in all three groups were the steepest on the first day, and then they were continuous gradually decreased until to the sixth week (Figure 4.8).

2.2 One-way analysis of variance and multiple comparisons of percent remaining force among three forms of orthodontic elastomeric chains in each period and among eight periods in the same form of elastomeric chains

The influence of time in a simulated tooth movement was evaluated on a week to week basis during six weeks. Analysis of variance was carried out to determine differences in percent remaining force values over times. Then, Duncan's multiple range test was following tested as shown in Table 4.7.

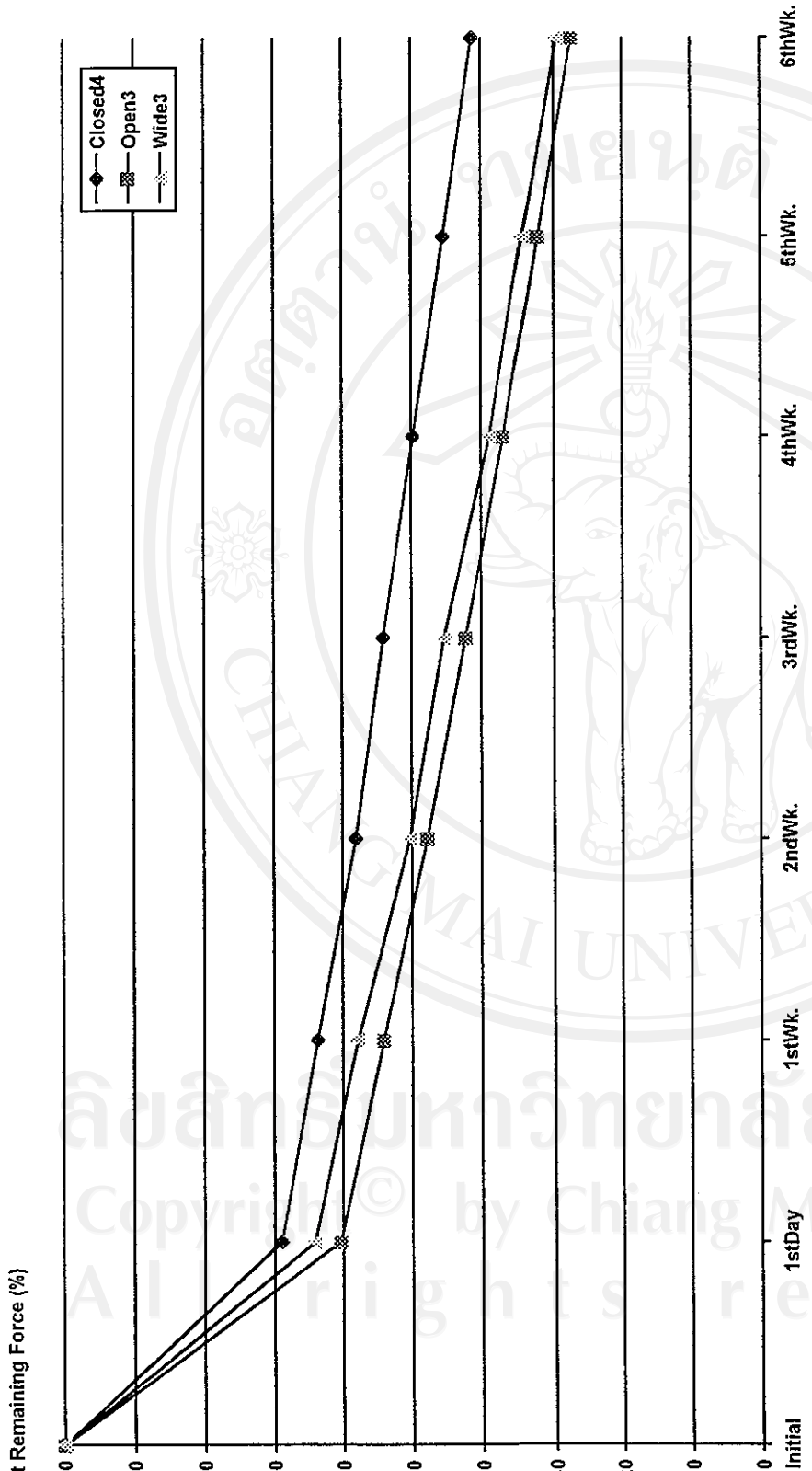

Figure 4.8 Percent remaining force of three forms of elastomeric chains in eight periods

Table 4.7 One-way ANOVA and multiple comparisons of percent remaining force among three forms of orthodontic elastomeric chains in seven periods by Duncan's multiple range test

Time	F-value	Duncan's test of percent remaining force		
		$\bar{X}_{closed}$ vs $\bar{X}_{open}$	$\bar{X}_{closed}$ vs $\bar{X}_{wide}$	$\bar{X}_{open}$ vs $\bar{X}_{wide}$
1st Day	111.040***	8.63**	4.89**	3.74**
1st Wk.	169.388***	9.46**	5.75**	3.71**
2nd Wk.	379.031***	10.40**	7.84**	2.56**
3rd Wk.	465.444***	11.87**	8.82**	3.05**
4th Wk.	792.542***	12.86**	10.93**	1.93**
5th Wk.	1115.304***	13.17**	11.15**	2.02**
6th Wk.	1145.048***	13.76**	11.65**	2.11**

* $p< 0.05$, ** $p< 0.01$, *** $p< 0.001$

The percent remaining forces among three forms of elastomeric chains showed significantly different to each other in all time periods ($p< 0.01$).

One-way ANOVA with repeated factor was used to compare the percent remaining force of all forms of elastomeric chains among eight periods.

Table 4.8 One-way ANOVA with repeated one factor of percent remaining force among eight periods of three forms of orthodontic elastomeric chains

Group	Percent remaining force (%)								F - value
	Initial	1st Day	1st Wk.	2nd Wk.	3rd Wk.	4th Wk.	5th Wk.	6th Wk.	
Closed	100.00 ± 0.00	68.95 ± 1.86	63.61 ± 1.70	58.13 ± 1.58	54.13 ± 1.41	49.70 ± 1.56	45.46 ± 1.27	41.27 ± 1.03	7545.35***
Open	100.00 ± 0.00	60.32 ± 2.55	54.15 ± 1.83	47.73 ± 1.69	42.26 ± 1.66	36.84 ± 1.51	32.29 ± 0.98	27.51 ± 1.15	8942.71***
Wide	100.00 ± 0.00	64.06 ± 2.29	57.86 ± 2.42	50.29 ± 1.28	45.31 ± 1.61	38.77 ± 0.86	34.31 ± 1.22	29.62 ± 1.39	9055.16***

* $p< 0.05$, ** $p< 0.01$, *** $p< 0.001$

The percent remaining force of all three forms of elastomeric chains showed significantly different among eight periods ($p< 0.001$).

Furthermore, Duncan's multiple range test was used for testing their differences.

Table 4.9 Multiple comparisons of percent remaining force among eight periods of closed elastomeric chain by Duncan's multiple range test

Closed	Initial	1st Day	1st Wk.	2nd Wk.	3rd Wk.	4th Wk.	5th Wk.	6th Wk.
$\bar{X}$ (%)	100.00	68.95	63.61	58.13	54.13	49.70	45.46	41.27
Initial								
1st Day	31.05**							
1st Wk.	36.39**	5.34**						
2nd Wk.	41.87**	10.82**	5.48**					
3rd Wk.	45.87**	14.82**	9.48**	4.00**				
4th Wk.	50.30**	19.25**	13.91**	8.43**	4.43**			
5th Wk.	54.54**	23.49**	18.15**	12.67**	8.67**	4.24**		
6th Wk.	58.73**	27.68**	22.34**	16.86**	12.86**	8.43**	4.19**	

* $p < 0.05$, ** $p < 0.01$

From Table 4.9, the percent remaining force of closed space elastomeric chains (C_4) showed significant differences in all periods ($p < 0.01$).

Table 4.10 Multiple comparisons of percent remaining force among eight periods of open elastomeric chains by Duncan's multiple range test

Open	Initial	1st Day	1st Wk.	2nd Wk.	3rd Wk.	4th Wk.	5th Wk.	6th Wk.
$\bar{X}$ (%)	100.00	60.32	54.15	47.73	42.26	36.84	32.29	27.51
Initial								
1st Day	39.68**							
1st Wk.	45.85**	6.17**						
2nd Wk.	52.27**	12.59**	6.42**					
3rd Wk.	57.74**	18.06**	11.89**	5.47**				
4th Wk.	63.16**	29.48**	17.31**	10.89**	5.42**			
5th Wk.	67.71**	28.03**	21.86**	15.44**	9.97**	4.55**		
6th Wk.	72.49**	32.81**	26.64**	20.22**	14.75**	9.33**	4.78**	

* $p < 0.05$, ** $p < 0.01$

From Table 4.10, the percent remaining force of open space elastomeric chains (O_3) in all eight periods showed significant differences ($p< 0.01$)

Table 4.11 Multiple comparisons of percent remaining force among eight periods of wide elastomeric chains by Duncan's multiple range test

Wide	Initial	1st Day	1st Wk.	2nd Wk.	3rd Wk.	4th Wk.	5th Wk.	6th Wk.
$\bar{X}$ (%)	100.00	64.06	57.86	50.29	45.31	38.77	34.31	29.62
Initial								
1st Day	35.94**							
1st Wk.	42.14**	6.20**						
2nd Wk.	49.71**	13.77**	7.57**					
3rd Wk.	54.69**	18.75**	12.55**	4.98**				
4th Wk.	61.23**	25.29**	19.09**	11.52**	6.54**			
5th Wk.	65.69**	29.75**	23.55**	15.98**	11.00**	4.46**		
6th Wk.	70.38**	34.44**	28.24**	20.67**	15.69**	9.15**	4.69**	

* $p< 0.05$, ** $p< 0.01$

From Table 4.11, the percent remaining forces of wide space elastomeric chains (W_3) were tested by Duncan's multiple range method. There were significant differences in all eight periods ($p< 0.01$).

2.3 Means and standard deviations of force decay, percent force decay, force decay rate and percent force decay rate at each time interval and the force decay pattern of three forms of orthodontic elastomeric chains during six-week period

2.3.1 The force decay, percent force decay, force decay rate and percent force decay rate at seven time intervals of three forms of orthodontic elastomeric chains

The means and standard deviations of force decay and percent force decay in seven time intervals during six weeks were demonstated in Table 4.12.

The amounts of force decay of all three groups were the greatest on the first day. Thereafter through six weeks, the force decay of each form of elastomeric chains decreased almost the same amount of force in each time interval.

Table 4.12 Means and standard deviations of force decay and percent force decay from time to time in seven time intervals during six weeks

Group / Time	Force decay (grams) and Percent force decay (%)					
	Closed space (C_4)		Open space (O_3)		Wide space (W_3)	
	$\bar{X} \pm SD$ (gm.)	$\bar{X} \pm SD$ (%)	$\bar{X} \pm SD$ (gm.)	$\bar{X} \pm SD$ (%)	$\bar{X} \pm SD$ (gm.)	$\bar{X} \pm SD$ (%)
0-1stD	115.88±7.67	31.05±1.86	148.84±9.98	39.68±2.55	114.35±7.35	35.94±2.29
1stD-1stWk.	19.91±7.93	5.34±2.14	23.15±8.88	6.17±2.37	19.72±7.56	6.19±2.37
1st-2ndWk.	20.42±6.01	5.47±1.62	24.07±6.77	6.42±1.81	24.12±6.17	7.72±1.91
2nd-3rdWk.	14.95±5.42	4.00±1.44	20.56±7.26	5.47±1.92	15.83±4.25	4.98±1.35
3rd-4thWk.	16.53±5.15	4.43±1.38	20.32±4.89	5.42±1.30	20.79±4.61	6.54±1.48
4th-5thWk.	15.79±4.38	4.24±1.19	17.04±4.35	4.55±1.18	14.21±3.19	4.46±0.99
5th-6thWk.	15.65±4.60	4.19±1.23	17.96±3.93	4.79±1.03	14.91±4.68	4.69±1.50
Total	207.02±5.83	58.73±1.03	257.04±8.13	72.49±1.15	209.69±6.63	70.53±1.61

Since the time durations between each measurement were unequal, so the force decay rate and percent force decay rate were calculated for comparable (Table 4.13).

The force decay rates and percent force decay rates in all three groups were also the greatest on the first day, but thereafter they were almost constant in the other time intervals.

Table 4.13 Means and standard deviations of force decay rate and percent force decay rate from time to time in seven time intervals during six weeks

Group / Time	Force decay rate (gm./day) and Percent force decay rate (% per day)					
	Closed space (C_4)		Open space (O_3)		Wide space (W_3)	
	$\bar{X}$ ± SD (gm./day)	$\bar{X}$ ± SD (%/day)	$\bar{X}$ ± SD (gm./day)	$\bar{X}$ ± SD (%/day)	$\bar{X}$ ± SD (gm./day)	$\bar{X}$ ± SD (%/day)
0-1stD	115.88±7.67	31.05±1.86	148.84±9.98	39.68±2.55	114.35±7.35	35.94±2.29
1stD-1stWk.	3.32±1.32	0.89±0.36	3.86±1.48	1.03±0.40	3.29±1.26	1.03±0.39
1st-2ndWk.	2.92±0.86	0.78±0.23	3.44±0.97	0.92±0.26	3.45±0.88	1.10±0.27
2nd-3rdWk.	2.14±0.77	0.57±0.20	2.94±1.04	0.78±0.27	2.26±0.61	0.71±0.19
3rd-4thWk.	2.36±0.74	0.63±0.20	2.90±0.70	0.77±0.18	2.97±0.66	0.93±0.21
4th-5thWk.	2.26±0.63	0.60±0.17	2.43±0.62	0.65±0.17	2.03±0.46	0.64±0.14
5th-6thWk.	2.24±0.66	0.60±0.18	2.57±0.56	0.68±0.15	2.13±0.67	0.67±0.21

2.3.2 The force decay pattern with simulated tooth movement of three forms of orthodontic elastomeric chains in 6 weeks period

The patterns of percent force decay and percent force decay rate with simulated tooth movement 0.5 millimeters per week of three forms of elastomeric chain were relatively similar. The force degradations were dramatically great on the first day, thereafter they maintained almost the same amount in the other time intervals especially the percent force decay rate pattern. The patterns of percent force decay and percent force decay rate were shown in Figure 4.9 and 4.10 respectively.

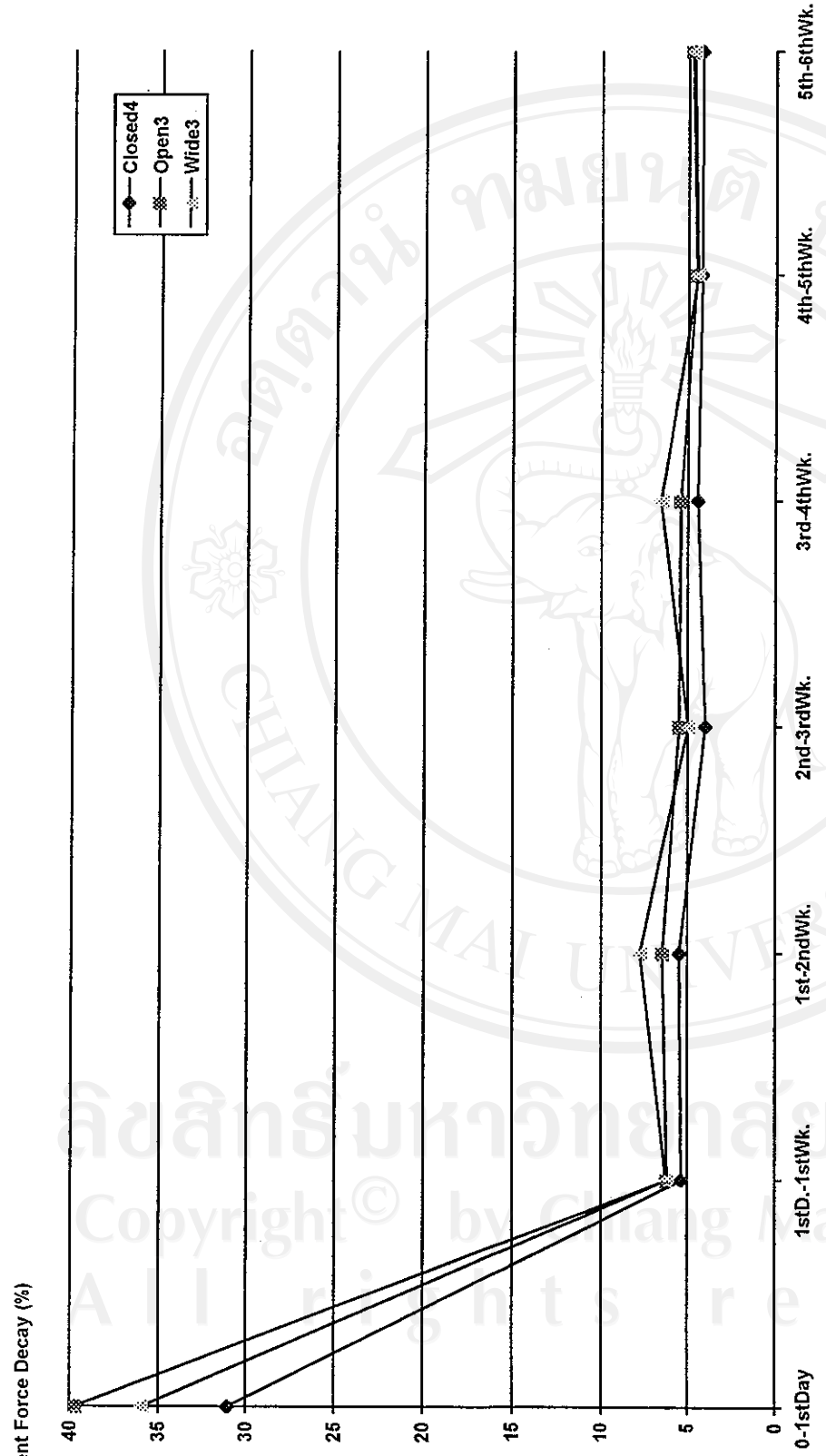

Figure 4.9 Percent force decay of three forms of elastomeric chain in seven time intervals

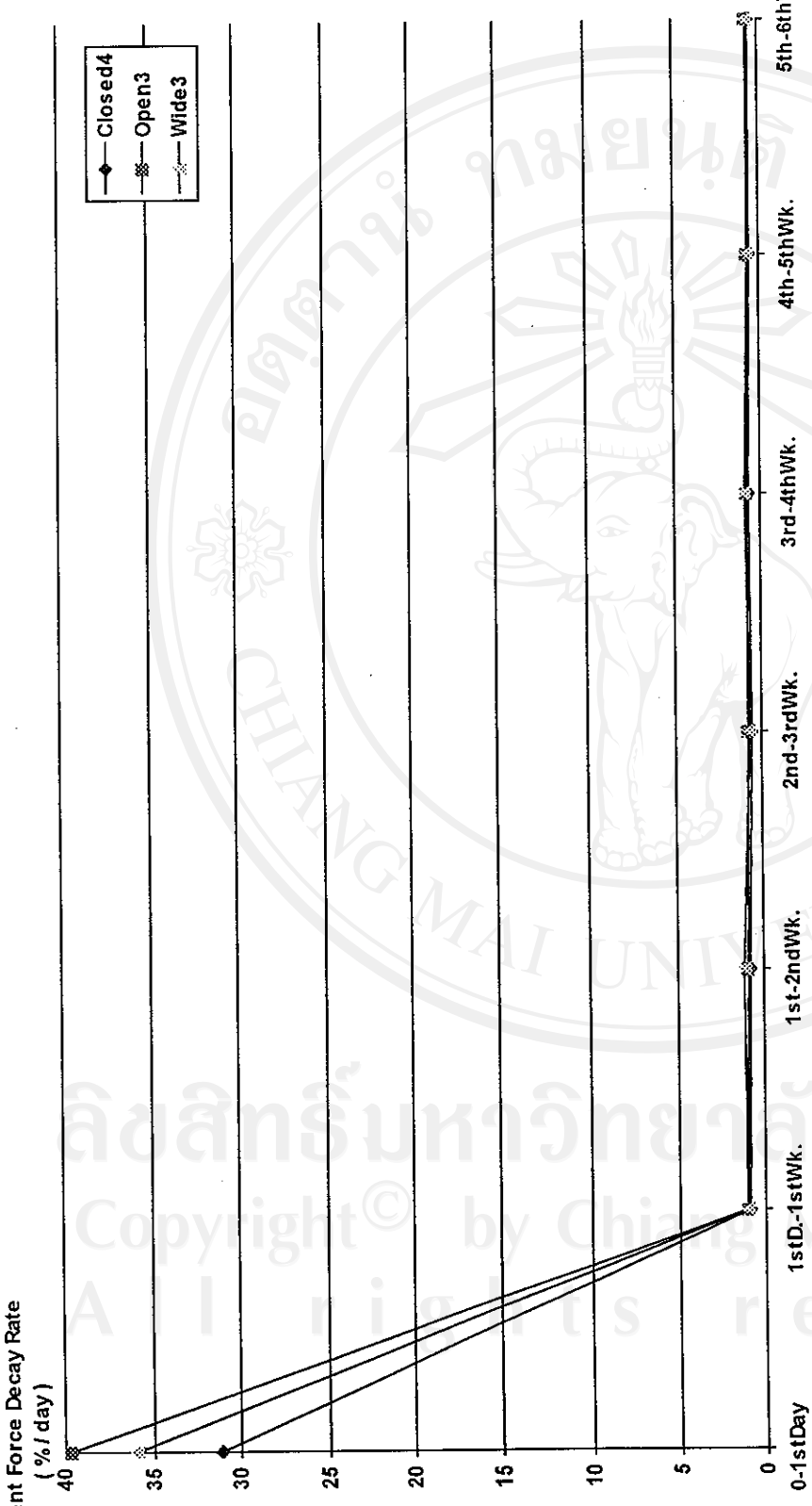

Figure 4.10 Percent force decay rate of three forms of elastomeric chain in seven time intervals

2.4 One-way analysis of variance and multiple comparisons of percent force decay rate among three forms of orthodontic elastomeric chains in each time interval and among seven time intervals in the same form of elastomeric chains

The percent force decay rates of three forms of elastomeric chains among seven time intervals were compared by one-way ANOVA. Following, Duncan's multiple range test was used for comparing them between each pair of three elastomeric chain forms (Table 4.14).

Table 4.14 One-way ANOVA and multiple comparisons of percent force decay rate among three forms of elastomeric chains in seven time intervals by Duncan's multiple range test

Time Interval	F-value	Duncan's test of percent force decay rate (% per day)		
		$\bar{X}_{closed}$ vs $\bar{X}_{open}$	$\bar{X}_{closed}$ vs $\bar{X}_{wide}$	$\bar{X}_{open}$ vs $\bar{X}_{wide}$
Initial - 1st D	111.040***	8.63**	4.89**	3.74**
1st D - 1st Wk	1.341	0.14	0.14	0.00
1st Wk - 2nd Wk	12.029***	0.14*	0.32**	0.18**
2nd Wk - 3rd Wk	6.627**	0.21**	0.14*	0.07
3rd Wk - 4th Wk	17.430***	0.14**	0.30**	0.16**
4th Wk - 5th Wk	0.610	0.05	0.04	0.01
5th Wk - 6th Wk	1.889	0.08	0.07	0.01

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The percent force decay rate showed significant differences among three forms of elastomeric chain in some time intervals as illustrated in Table 4.14.

The percent force decay rates of each form of elastomeric chain were also compared among seven time intervals by one-way ANOVA with repeated one factor (Table 4.15).

Table 4.15 One-way ANOVA with repeated one factor of percent force decay rate among seven time intervals of three forms of orthodontic elastomeric chains

Time / Group	Percent force decay rate (% per day)							F - value
	Initial-1st Day	1st D-1st Wk.	1st-2nd Wk.	2nd-3rd Wk.	3rd-4th Wk.	4th-5th Wk.	5th-6th Wk.	
Closed	31.05 ± 1.86	0.89 ± 0.36	0.78 ± 0.23	0.57 ± 0.20	0.63 ± 0.20	0.60 ± 0.17	0.60 ± 0.18	1036.41***
Open	39.68 ± 2.55	1.03 ± 0.40	0.92 ± 0.26	0.78 ± 0.27	0.77 ± 0.18	0.65 ± 0.17	0.68 ± 0.15	1309.34***
Wide	35.94 ± 2.29	1.03 ± 0.39	1.10 ± 0.27	0.71 ± 0.19	0.93 ± 0.21	0.64 ± 0.14	0.67 ± 0.21	1107.45***

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

From Table 4.15, the percent force decay rate of three forms of elastomeric chains among seven time intervals showed significant differences ($p < 0.001$). Consequently, Duncan's multiple range method was done for multiple comparisons test (Table 4.16, 4.17, 4.18).

Table 4.16 Multiple comparisons of percent force decay rate of closed space elastomeric chain among seven time intervals by Duncan's multiple range test

Closed	0-1st Day	1st D-1st Wk.	1st-2nd Wk.	2nd-3rd Wk.	3rd-4th Wk.	4th-5th Wk.	5th-6th Wk.
$\bar{X}$(%/day)	31.05	0.89	0.78	0.57	0.63	0.60	0.60
0-1st Day							
1st D-1st Wk.	30.16**						
1st-2nd Wk.	30.27**	0.11					
2nd-3rd Wk.	30.48**	0.32	0.21				
3rd-4th Wk.	30.42**	0.26	0.15	0.06			
4th-5th Wk.	30.45**	0.29	0.18	0.03	0.03		
5th-6th Wk.	30.45**	0.29	0.18	0.03	0.03	0.00	

* $p < 0.05$, ** $p < 0.01$

From Duncan's multiple range test of the percent force decay rate of closed space elastomeric chains, there were significant differences only on the

first day interval to the other time intervals ($p < 0.01$). The differences among the remained time intervals after one day were not significant (Table 4.16).

Table 4.17 Multiple comparisons of percent force decay rate of open space elastomeric chains among seven time intervals by Duncan's multiple range test

Open	0-1st Day	1st D-1st Wk.	1st-2nd Wk.	2nd-3rd Wk.	3rd-4th Wk.	4th-5th Wk.	5th-6th Wk.
$\bar{X}$(%/day)	39.68	1.03	0.92	0.78	0.77	0.65	0.68
0-1st Day							
1st D-1st Wk.	38.65**						
1st-2nd Wk.	38.76**	0.11					
2nd-3rd Wk.	38.90**	0.25	0.14				
3rd-4th Wk.	38.91**	0.26	0.15	0.01			
4th-5th Wk.	39.03**	0.38	0.27	0.13	0.12		
5th-6th Wk.	39.00**	0.35	0.24	0.10	0.09	0.03	

* $p < 0.05$, ** $p < 0.01$

The percent force decay rate of open elastomeric chains showed significant differences only on the first day to the other time intervals ($p < 0.01$). The differences among the remained time intervals after one day were not significant (Table 4.17).

Table 4.18 Multiple comparisons of percent force decay rate of wide space elastomeric chains among seven time intervals by Duncan's multiple range test

Wide	0-1st Day	1st D-1st Wk	1st-2nd Wk.	2nd-3rd Wk.	3rd-4th Wk.	4th-5th Wk.	5th-6th Wk.
$\bar{X}$(%/day)	35.94	1.03	1.10	0.71	0.93	0.64	0.67
0-1st Day							
1st D-1st Wk.	34.91**						
1st-2nd Wk.	34.84**	0.07					
2nd-3rd Wk.	35.23**	0.32	0.39				
3rd-4th Wk.	35.01**	0.10	0.17	0.22			
4th-5th Wk.	35.30**	0.39	0.46	0.07	0.29		
5th-6th Wk.	35.27**	0.36	0.43	0.04	0.26	0.03	

* $p < 0.05$, ** $p < 0.01$

From Table 4.18, the percent force decay rate of wide elastomeric chains showed significant differences only on the first day to the other six time intervals ($p < 0.01$).