CHAPTER IV
RESULTS

The results of this study would presented as follows:

Part I : The magnetic force generated by the commercial and orthodontic magnets

1. Means ($\bar{X}$), standard deviations (SD), and estimation of means (μ) of magnetic forces of orthodontic and commercial magnets in each group of samples.

2. The comparison of mean of magnetic force of the commercial magnets and orthodontic magnets attracting to orthodontic bracket by t - test.

3. The correlations between magnetic force and size of commercial magnets by compare the magnetic force among three sizes of commercial magnets (6.0x6.0x2.0 mm., 8.0x8.0x2.0 mm., 10.0x10.0x2.0 mm)..

Part II : The composition and crystal structure of the commercial and orthodontic magnets.

Part I : The magnetic force generated by the commercial and orthodontic magnets

1) Means ($\bar{X}$), standard deviations (SD), and estimation of means (μ) of magnetic forces of orthodontic and commercial magnets in each group of samples.

One group of orthodontic magnet (3.7mm.ϕx 2.0 mm.) and four groups of commercial magnets (3.28x3.28x2.0 mm., 6.0x6.0x2.0 mm., 8.0x8.0x2.0 mm., 10.0x10.0x2.0 mm.) were measured magnetic forces attracting to orthodontic bracket in various distances (initial, 0.25, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0 millimeters). The magnetic force of each sample was presented in Appendix. Means, standard deviations and estimation of means of magnetic forces were presented in Table 4.1 and the force – distance curve of five groups were shown in Figure 4.1.

Table 4.1 Means, standard deviations and estimation of means of magnetic forces generated by orthodontic magnet (3.7mm.ϕ x 2.0 mm.) and commercial magnets (3.28x3.28x2.0 mm., 6.0x6.0x2.0 mm., 8.0x8.0x2.0 mm., 10.0x10.0x2.0 mm.)

Type/size	Orthodontic magnet (N=12) (3.7ϕ x 2.0 mm.)			Commercial magnet (N=20) (3.28x3.28x2.0 mm.)			Commercial magnet (N=20) (6.0x6.0x2.0 mm.)			Commercial magnet (N=20) (8.0x8.0x2.0 mm.)			Commercial magnet (N=20) (10.0x10.0 x2.0 mm.)		
Distance (mm.)	Magnetic forces (g)			Magnetic forces (g)			Magnetic forces (g)			Magnetic forces (g)			Magnetic forces (g)		
	$\bar{x}$	SD	μ	$\bar{x}$	SD	μ	$\bar{x}$	SD	μ	$\bar{x}$	SD	μ	$\bar{x}$	SD	μ
initial	53.55	11.24	60.69-46.41	76.89	24.77	88.48-65.30	44.42	6.31	47.37-41.46	21.6	3.46	23.23-19.99	13.4	2.12	14.39-12.40
0.25	33.75	5.54	37.27-30.22	45.41	12.58	51.29-39.52	36.52	3.44	38.13-34.91	19.93	3.02	21.34-18.51	12.51	1.91	13.40-11.61
0.5	21.83	2.51	23.42-20.23	28.72	6.74	31.87-25.56	30.11	3.35	31.68-28.54	18.58	2.61	19.80-17.36	12.90	1.94	12.99-11.18
1.0	10.58	2.39	12.10-9.05	14.69	2.88	16.04-13.34	18.64	1.73	19.45-17.82	15.38	1.66	16.16-14.59	11.02	1.84	11.88-10.16
1.5	6.61	1.89	7.81-5.40	9.42	2.47	10.57-8.26	12.60	1.51	13.31-11.89	12.41	2.03	13.36-11.45	10.14	1.79	10.98-9.29
2.0	5.25	1.80	6.3-4.10	7.44	2.09	8.42-6.46	8.71	1.42	9.38-8.04	10.52	2.00	11.45-9.58	9.18	1.93	10.09-8.27
2.5	4.04	2.15	5.41-2.67	6.12	2.43	7.26-4.98	6.49	1.18	7.04-5.93	8.57	2.02	9.51-7.62	8.08	1.83	8.93-722
3.0	3.67	1.86	4.85-2.49	6.32	2.88	7.67-4.97	5.23	1.00	5.69-4.76	7.75	2.27	8.81-6.69	7.23	1.87	8.10-6.35
4.0	4.17	1.66	5.23-3.11	5.96	2.86	7.30-4.62	4.01	0.85	4.40-3.61	6.58	2.17	7.59-5.56	5.71	1.82	6.56-4.85
5.0	3.56	1.49	4.52-2.61	5.66	2.59	6.88-4.44	1.44	1.44	4.37-3.03	4.74	1.99	5.67-3.80	4.78	1.88	5.66-3.89

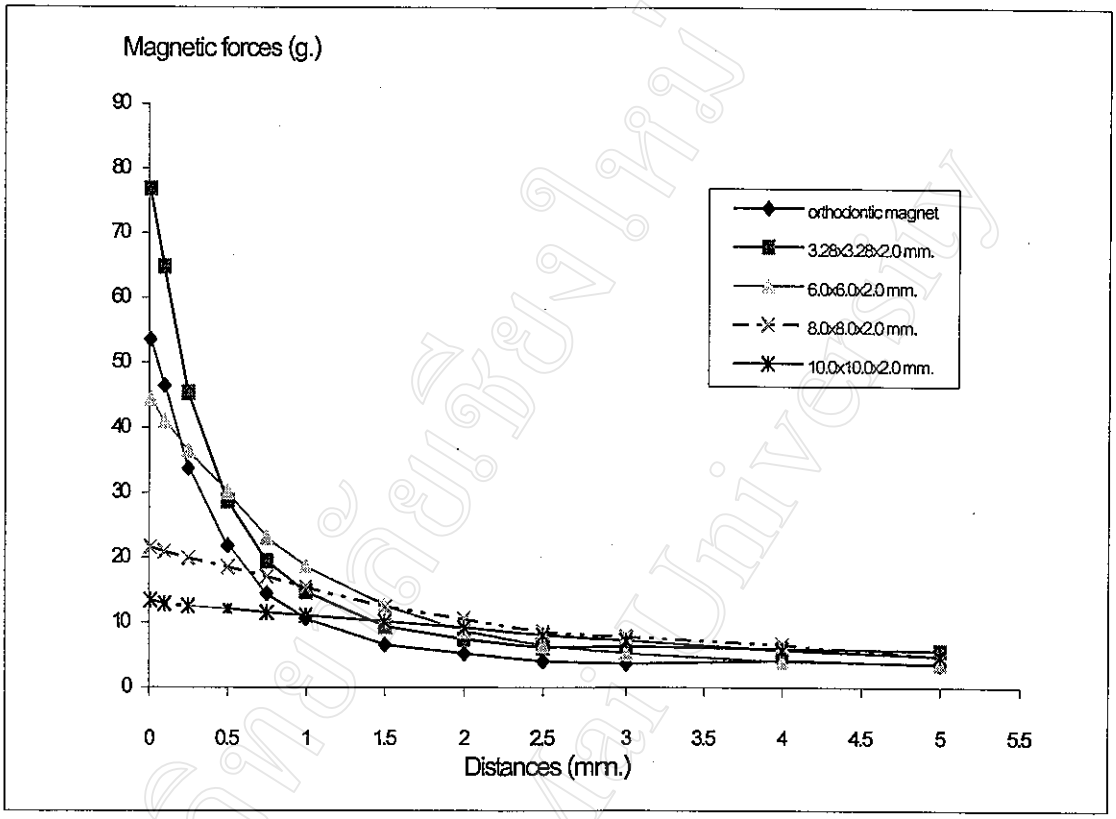

Figure 4.1 Force – distance curve of orthodontic magnets (3.7mm.ϕx2.0 mm.) and commercial magnets (3.28x3.28x2.0 mm., 6.0x6.0x2.0 mm., 8.0x8.0x2.0 mm., 10.0x10.0 x2.0 mm.)

From Figure 4.1, The force–distance curve was hyperbolic. When the distance between the magnet and orthodontic bracket was more than a few millimeters apart, the mean of magnetic force dropped dramatically. At distances; initial, 0.25, 0.5, 1.0, 1.5 millimeters, group 1 (orthodontic magnets, 3.7mm.ϕx2.0 mm.) and group 2 (commercial magnets, 3.28x3.28x2.0 mm.) exhibited a steeper force – distance curve than groups 3, 4, 5 (commercial magnets, 6.0x6.0x2.0 mm., 8.0x8.0x2.0 mm., 10.0x10.0x2.0 mm.). It was shown that at distances; initial, 0.25, 0.5, 1.0, 1.5 millimeters, when the distance increased the mean of magnetic forces of group 1 (orthodontic magnets, 3.7mm.ϕx2.0

mm.) and group 2 (commercial magnets, 3.28x3.28x2.0 mm.) dropped greater than groups 3, 4, 5 (commercial magnets, 6.0x6.0x2.0 mm., 8.0x8.0x2.0 mm., 10.0x10.0x2.0 mm.).

From Table 4.1, at initial, the mean of magnetic force of group 2 (commercial magnets, 3.28x3.28x2.0 mm.) were greatest. The sequence of mean of magnetic force from maximum to minimum was group 2 (commercial magnets, 3.28x3.28x2.0 mm.), group 1(orthodontic magnets, 3.7mm.ϕx2.0 mm.), group 3 (commercial magnets, 6.0x6.0x2.0 mm.), group 4 (commercial magnets, 8.0x8.0x2.0 mm.) and group 5 (commercial magnets, 10.0x10.0x2.0 mm.). However, at distances 0.5, 1.0, 1.5 millimeters, the mean of magnetic force of group 3 (commercial magnets, 6.0x6.0x2.0 mm.) was greatest. At distances 2.0, 2.5, 3.0, 4.0, 5.0 millimeters the mean of magnetic forces of five groups showed slightly difference.

2. The comparison of mean of magnetic force of commercial and orthodontic magnets attracting to orthodontic bracket by t – test.

The commercial magnets (3.28x3.28x2.0 mm.) and orthodontic magnets (3.7mm.ϕx2.0 mm.) being used in this study had relatively equal volume but the shapes were different. The shape of commercial magnet was cubic but the shape of orthodontic magnet was cylinder. T-test was used to compare the mean of magnetic force of orthodontic magnets (3.7mm.ϕx2.0 mm.) and commercial magnets (3.28x3.28x2.0 mm.) attracting to orthodontic bracket (Table 4.2).

Table 4.2 t- test between mean of magnetic force of orthodontic magnet (3.7mm.ϕx2.0 mm.), commercial magnets (3.28x3.28x2.0 mm.) attract to orthodontic bracket in various distances.

Type	Orthodontic magnet (N=12)		Commercial magnet (N =20)		
Distance (mm.)	Magnetic force (g)		Magnetic force (g)		t - test
	$\bar{X}$	SD	$\bar{X}$	SD	
Initial	53.55	11.24	76.89	24.77	3.065**
0.25	33.75	5.54	45.41	12.58	3.024**
0.5	21.83	2.51	28.72	6.74	4.116***
1.0	10.58	2.39	14.69	2.88	4.146***
1.5	6.61	1.89	9.42	2.47	3.375**
2.0	5.25	1.80	7.44	2.09	3.013**
2.5	4.04	2.15	6.12	2.43	2.443*
3.0	3.67	1.86	6.32	2.88	2.833**
4.0	4.17	1.66	5.96	2.86	2.237*
5.0	3.56	1.49	5.66	2.59	2.545*

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

Table 4.2 showed a significant difference in the mean of magnetic force of orthodontic magnets (3.7mm.ϕx2.0 mm.) and commercial magnets (3.28x3.28x2.0 mm.) attracting to orthodontic bracket in various distances, at $p<0.001$, $p<0.01$, $p<0.05$. The commercial magnets had the standard deviation of magnetic force more than orthodontic magnets. It was shown that the mean of magnetic force of commercial magnets were more different between individual.

The force-distance curve of orthodontic magnets (3.7mm.ϕx2.0 mm.) and commercial magnets (3.28x3.28x2.0 mm.) were shown in Figure 4.2.

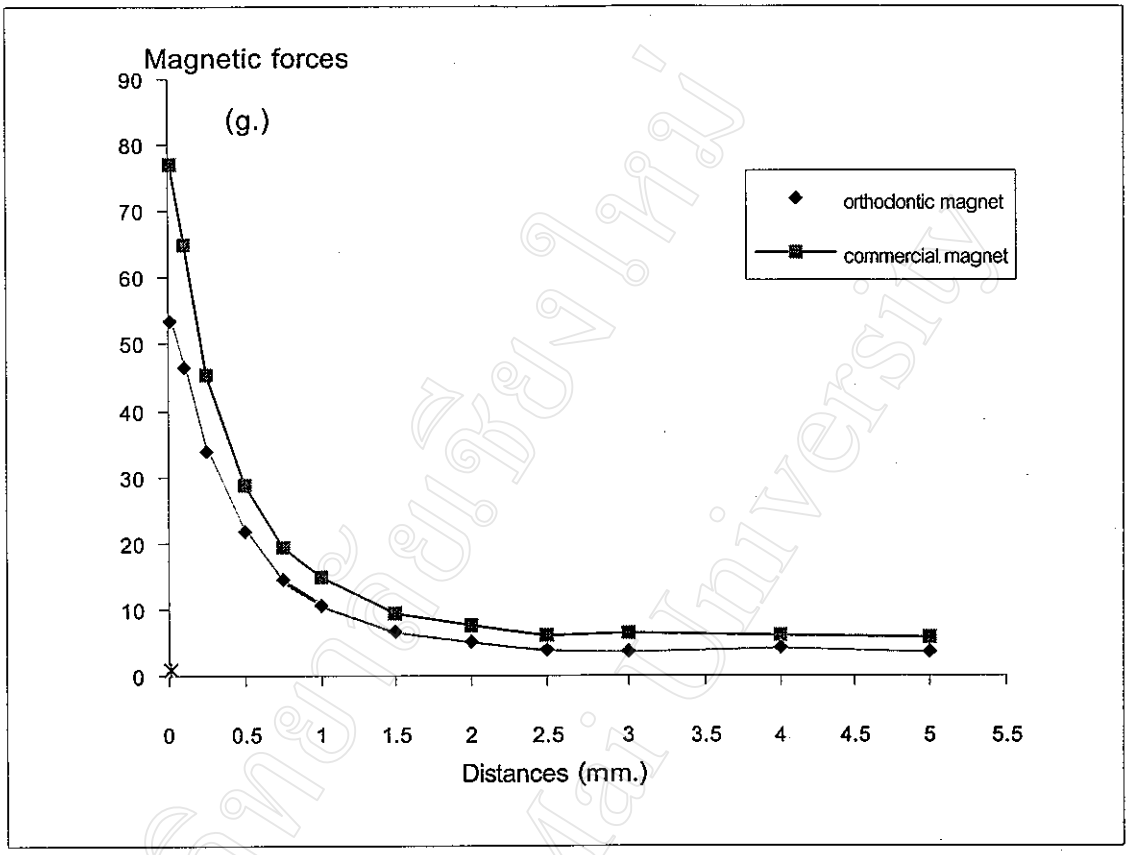

Figure 4.2 Force – distance curve of orthodontic magnets (3.7mm.ϕx2.0 mm.) and commercial magnets (3.28x3.28x2.0 mm.)

3. The correlations between magnetic force and size of commercial magnets.

Three sizes of commercial magnets were used in this investigate; 6.0x6.0x2.0 mm. (group III), 8.0x8.0x2.0 mm. (group IV) and 10.0x10.0x2.0 mm. (group V). One way analysis of variance (ANOVA) was used for find the correlations between the magnetic force of commercial magnet attracting to orthodontic bracket and size of commercial magnet by compare the magnetic force among three sizes of commercial magnets in various distances.

Table 4.3 One way ANOVA and multiple comparisons of magnetic force among three sizes of commercial magnets in various distances by Scheffe's multiple range test

Distances	F-value	Scheffe's test of magnetic forces		
		$\bar{X}_{III}$ vs $\bar{x}_{IV}$	$\bar{X}_{III}$ vs $\bar{x}_{V}$	$\bar{X}_{IV}$ vs $\bar{x}_{V}$
Initial	274.900***	22.805***	31.020***	8.215***
0.25 mm.	367.418***	16.595***	24.015***	7.420***
0.5 mm.	228.912***	11.530***	18.025***	6.495***
1.0 mm.	95.254***	3.260***	7.615***	4.355***
1.5 mm.	11.637***	0.195	2.465***	2.270***
2.0 mm.	5.358**	-1.805*	-0.470	1.335
2.5 mm.	7.997***	-2.080***	-1.590	0.490
3.0 mm.	10.998***	-2.525***	-2.000**	0.525
4.0 mm.	11.705***	-2.570***	-1.700*	0.870
5.0 mm.	2.316	-1.035	-1.075	-0.04

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

$\bar{X}_{III}$ = Mean of magnetic force of commercial magnet of group III (6.0x6.0x2.0 mm.)

$\bar{X}_{IV}$ = Mean of magnetic force of commercial magnet of group IV (8.0x8.0x2.0 mm.)

$\bar{X}_{V}$ = Mean of magnetic force of commercial magnet of group V (10.0x10.0x2.0 mm.)

Table 4.3 showed a significant differences in the mean of magnetic force among three sizes of commercial magnets ($p<0.001$) at distances; initial, 0.25, 0.5, 1.0 millimeters. Accordingly, there was high negatively correlation between magnetic force and size of commercial magnets at distances; initial, 0.25, 0.5, 1.0 millimeters. It was shown that smaller sizes of commercial magnet exhibited higher magnetic force of magnet attracting to orthodontic bracket than bigger sizes.

At distances; 1.5, 2.0, 2.5, 3.0, 4.0, 5.0 millimeters, there were significant differences in the magnetic force among three sizes of commercial magnets in only some distance intervals. Accordingly, there was no correlation between size of commercial magnet and magnetic force at distances; 1.5, 2.0, 2.5, 3.0, 4.0, 5.0 millimeters.

Part II : The composition and crystal structure of commercial and orthodontic magnets.

A. The composition of orthodontic and commercial magnets

The composition of orthodontic and commercial magnets was analyzed by energy dispersive X-ray microanalysis (EDX) and the morphology of orthodontic and commercial magnets was confirmed by scanning electron microscope (SEM). The morphology of orthodontic and commercial magnets were shown in Figure 4.3 and Figure 4.4.

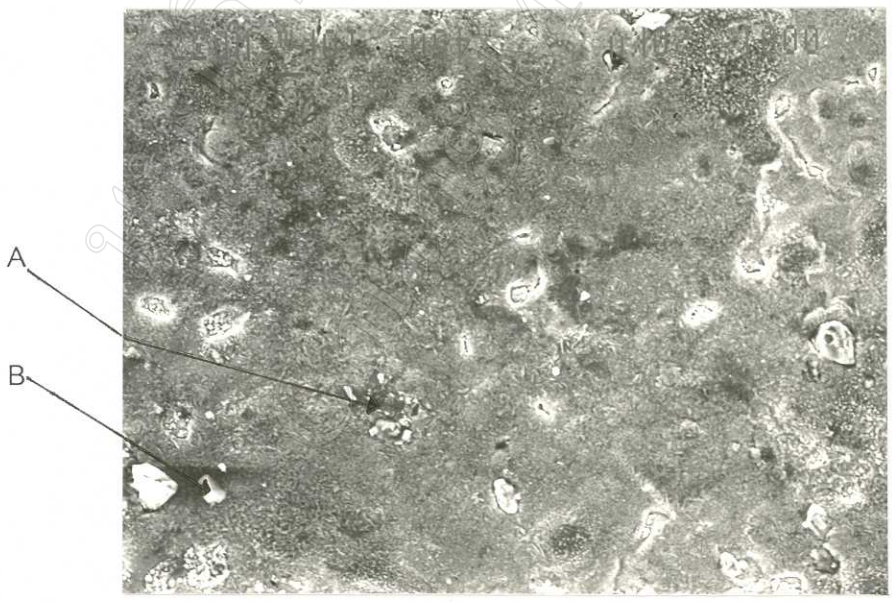

Figure 4.3 SEM photomicrograph showed morphology of orthodontic magnet surface (x450 magnification), A – dark grain, B-light grain

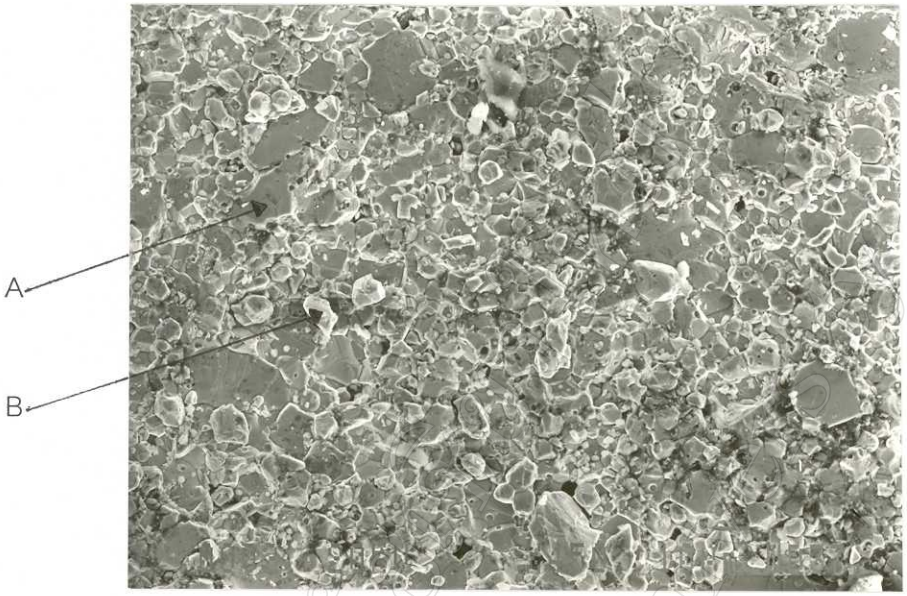

Figure 4.4 SEM photomicrograph showed morphology of commercial magnet surface (x450 magnification), A – dark grain, B-light grain

From Figure 4.3 and Figure 4.4 the micrograph of the orthodontic and commercial magnets were a grain in the casting. The morphology of orthodontic and commercial magnets surface were heterogenous. The main surface of orthodontic magnet was the dark grains and substituted with some light grains. The surface of commercial magnet was combined with back and white grains in different grain sizes and shapes.

The composition of each sample were investigated by energy-dispersive analysis. Figure 4.5 – 4.8 showed graph of intensity of each component in dark and light area of orthodontic and commercial magnets.

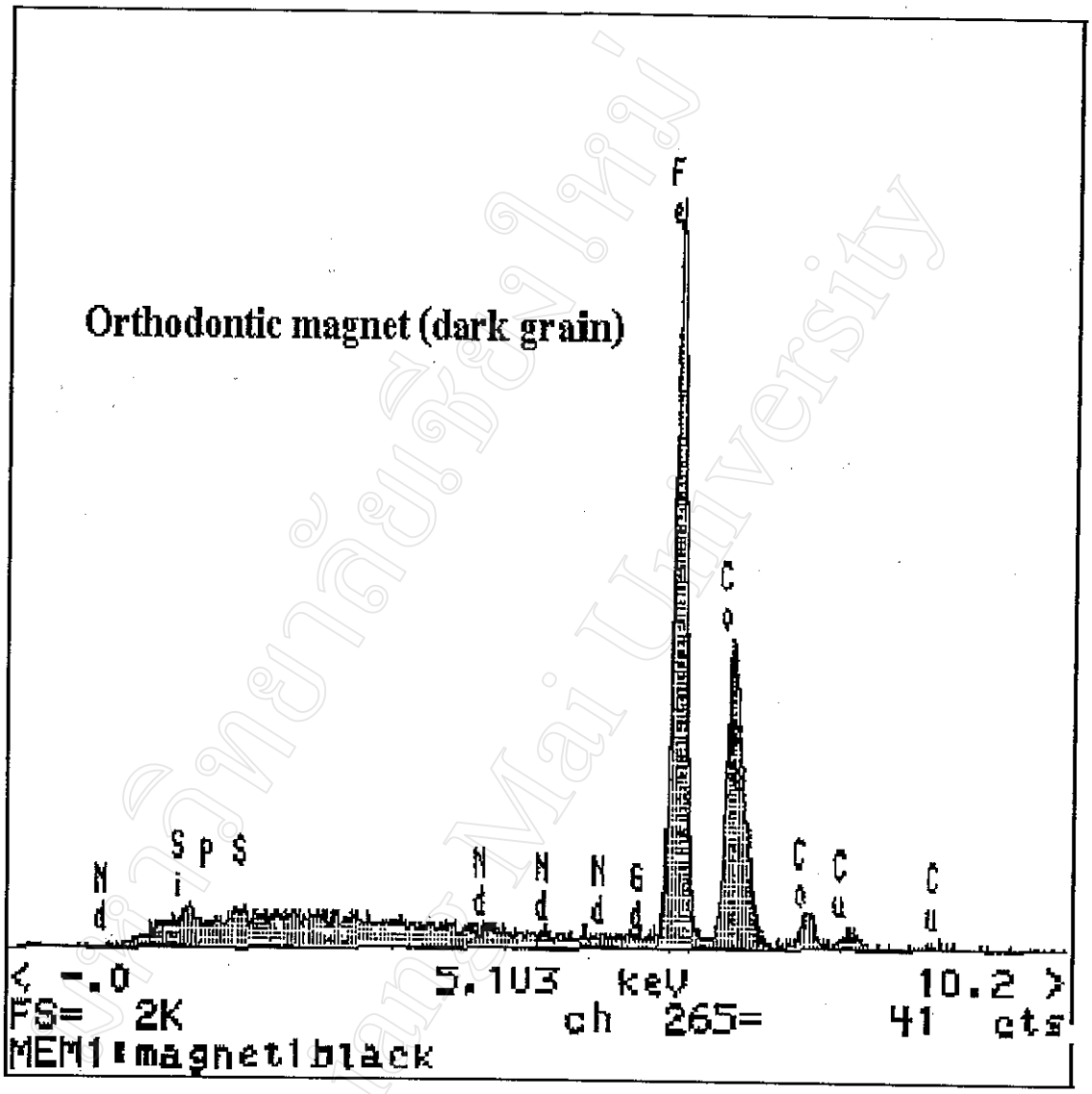

Figure 4.5 Graph showed intensity of each component in dark grain of orthodontic magnet (group 1)

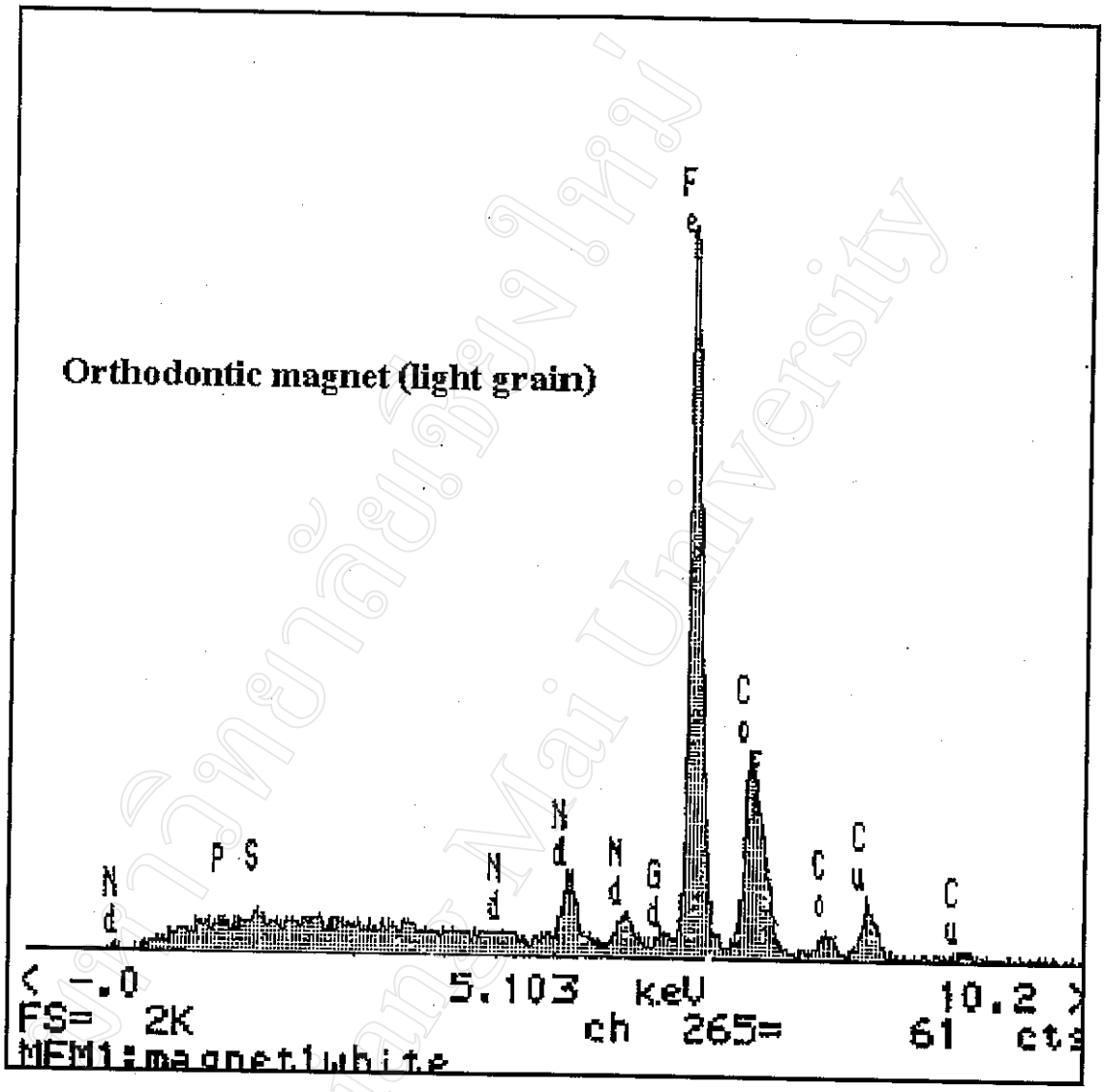

Figure 4.6 Graph showed intensity of each component in light grain of orthodontic magnet (group 1)

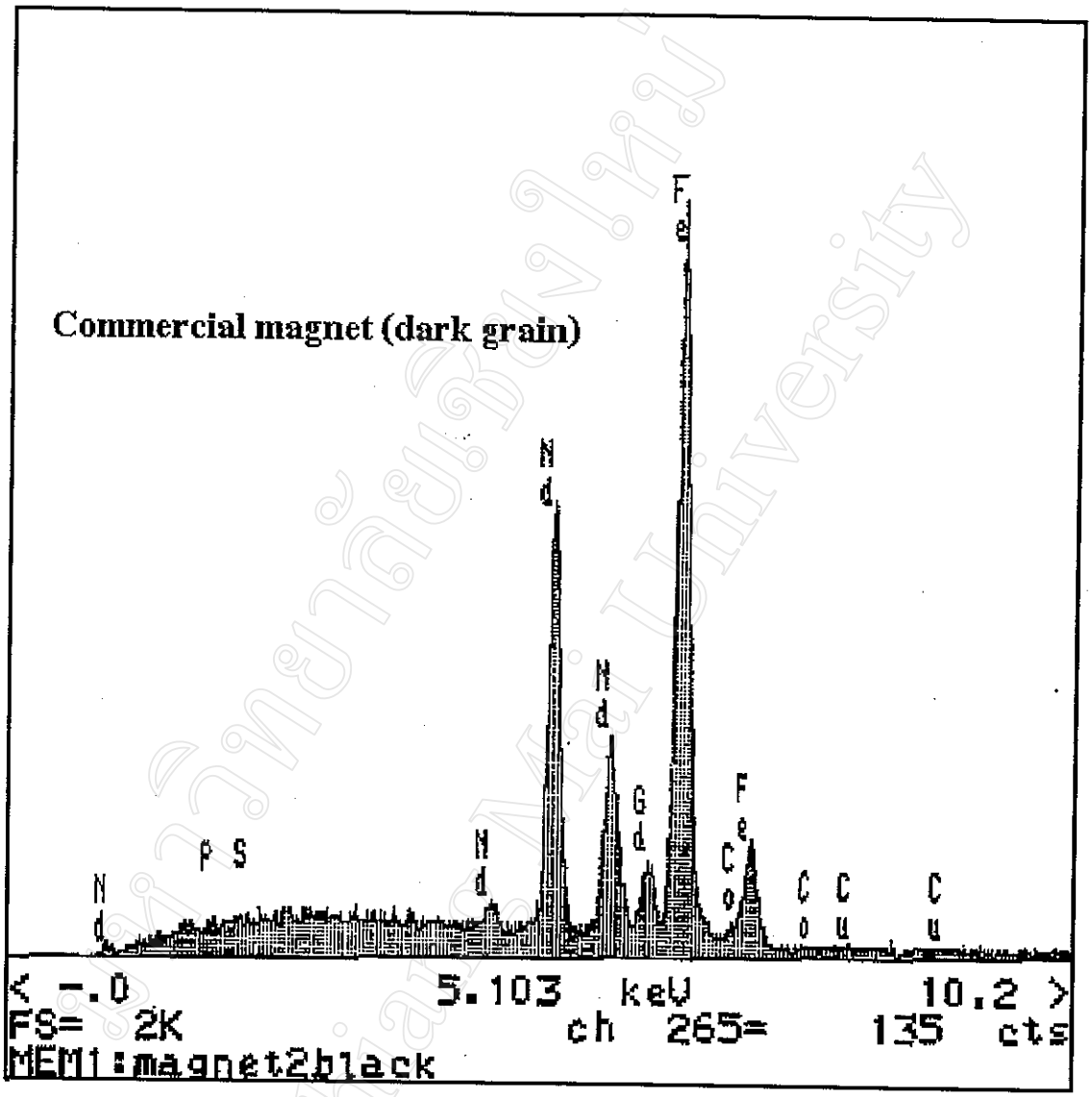

Figure 4.7 Graph showed intensity of each component in dark grain of commercial magnet (group 2)

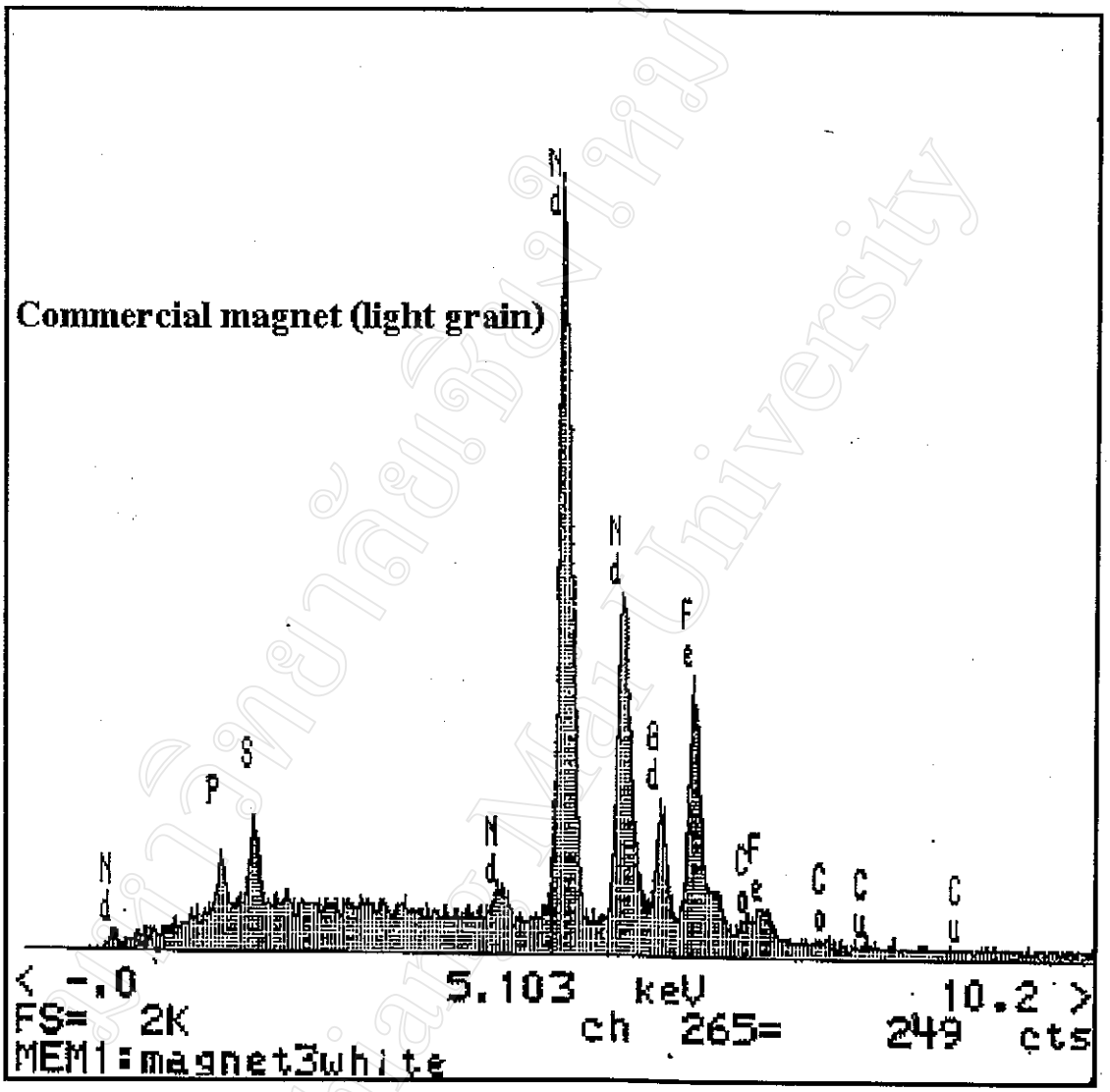

Figure 4.8 Graph showed intensity of each component in light grain of commercial magnet (group 2)

From Figure 4.5 and Figure 4.6 the composition in dark grain (black area) of orthodontic magnet consisted of iron (Fe), cobalt (Co), copper (Cu) and the composition in light grain of orthodontic magnet consisted of iron (Fe), cobalt (Co), copper (Cu), neodymium (Nd), gadolinium (Gd). The main composition in dark and light grain of orthodontic magnet were iron (Fe), cobalt (Co). The component which has greatest intensity in black and white area of orthodontic magnet was iron (Fe).

From Figure 4.7 and Figure 4.8 the composition in dark grain of commercial magnet consisted of iron (Fe), cobalt (Co), copper (Cu), neodymium (Nd), gadolinium (Gd) and the composition in light grain of commercial magnet consisted of iron (Fe), cobalt (Co), neodymium (Nd), gadolinium (Gd). The main composition in dark and light grain of commercial magnet were neodymium (Nd) and iron (Fe). The component which has greatest intensity in dark grain of commercial magnet was iron (Fe) but the component which has greatest intensity in light grain of commercial magnet was neodymium (Nd).

B The crystal structure of the commercial and orthodontic magnets

The crystal structure of orthodontic and commercial magnets were investigated by x-ray diffraction analysis. Figure 4.9-4.10 showed the graphs between intensity (Y-axis) and 2θ (X-axis), and Table 4.4 and Table 4.5 showed x-ray diffraction data of orthodontic and commercial magnets.

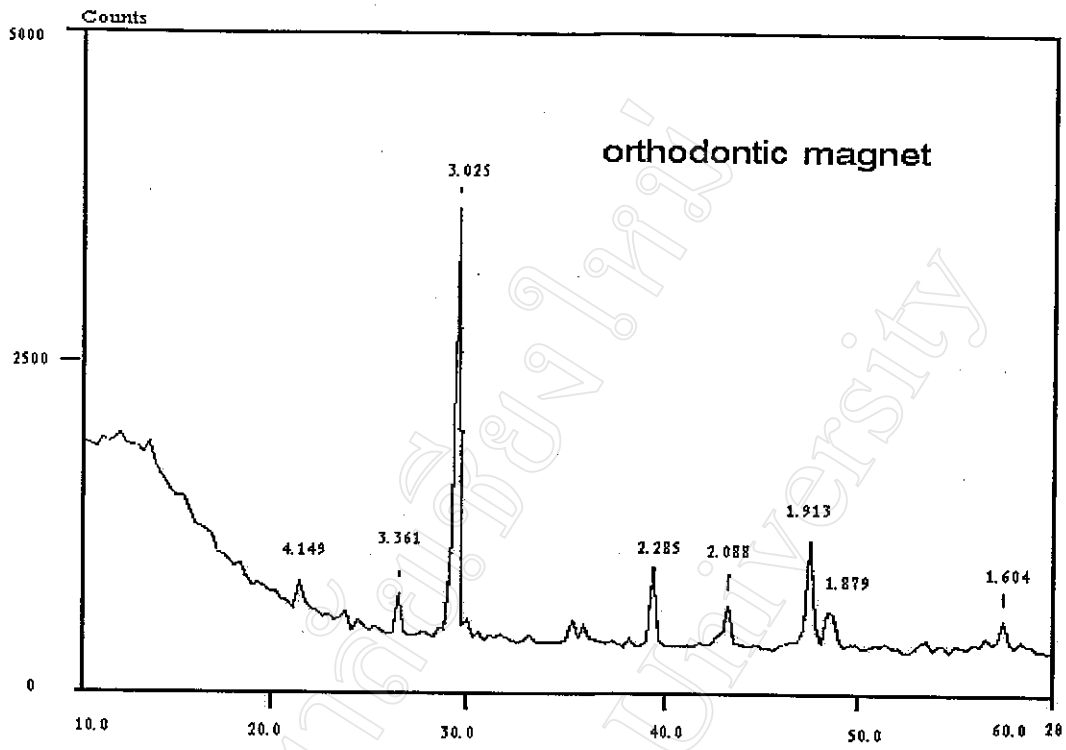

Figure 4.9 X-ray diffraction pattern of orthodontic magnet.

Table 4.4 X-ray diffraction data of orthodontic magnet.

2θ (°)	D (A')	I (count)	I/I
21.400	4.149	841	23
26.500	3.361	747	20
29.500	3.025	3671	100
39.400	2.285	947	26
43.300	2.088	652	18
47.500	1.913	1151	31
48.400	1.879	616	17
57.400	1.604	544	15

θ = the angle between the incident rays and atomic plane

D = the distance between successive atomic plances

I = intensity

I/I = intensity ratio

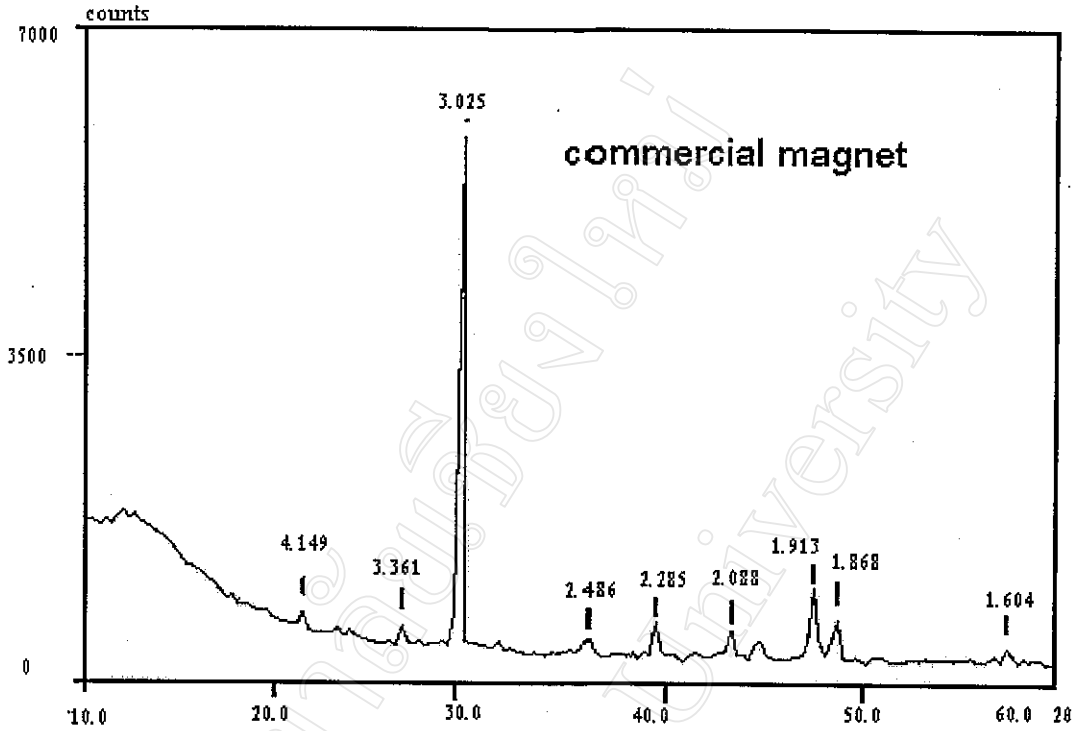

Figure 4.10 X-ray diffraction pattern of commercial magnet.

Table 4.5 X-ray diffraction data of commercial magnet.

2θ (°)	D (A')	I (count)	I/I
21.400	4.149	778	14
26.500	3.361	633	12
29.500	3.025	5488	100
36.100	2.486	497	9
39.400	2.285	674	12
43.300	2.088	573	10
47.500	1.913	1024	19
48.700	1.868	691	13
57.400	1.604	382	7

θ = the angle between the incident rays and atomic plane

D = the distance between successive atomic plances

I = intensity

I/I = intensity ratio

From Figure 4.9, Figure 4.10 and Table 4.4, Table 4.5, d-spacing values of orthodontic magnet following by intensity from maximum to minimum were 3.025, 1.913, 2.285 and d-spacing values of commercial magnet following by intensity from maximum to minimum were 3.025, 1.913, 4.149. The data of from these studies were compared with data base of JCPDS file. The data of JCPDS file which has the series of d-spacing value equal the series of d-spacing value of orthodontic and commercial magnets could not be found. However, some data of JCPDS file were similar to the data of orthodontic and commercial magnets such as Nd_2O_3 (3.01, 3.43, 1.98), FeGdC (2.99, 1.99, 1.73), NdB_6 (2.91, 4.12, 1.85).