

CHAPTER IV

RESULTS

The stress distribution and the total displacement of three types of OMI in bone models [Type A: AMI (ADTEC, Thailand), Type B: Jeil (Jeil Medical Corp., Korea) and Type C: Forestadent (Forestadent, Germany)] at different loading forces and directions was measured.

The Von Mises stress which indicated the durable of OMI model during loading experiments was evaluated after the loading forces of 2, 5 and 10 N at the direction of 0°, 30°, 45°, 60° and 90° were transferred as shown in table 2, 3, 4, 5 and 6, respectively. All of the stress values in all models were not more than the yield strength of titanium or 790 MPa (Boyer *et al.*, 1994). As a results, type A, B and C OMI were strong enough for supporting the loading force of 2, 5 and 10 N in different directions without any fractures.

In the meantime, the total displacement or the shifting distances of OMI after loading displayed different results. The total displacement of less than 0.01 mm represented the acceptable stability while the excess value (> 0.01 mm) referred to the mobility of OMI models (Hong *et al.*, 2011).

At 0, 30 and 45 degree with the loading force of 2 N, the total displacement of all OMI models were less than 0.01 mm. For 5 N loading force at the same directions he total displacements of type A and B OMI models were less than 0.01 mm whereas type C OMI model showed more value than the limitation of 0.01 mm. As a result, type A and B OMIs showed more stability with the loading force of 5 N than type C. Furthermore, at the loading force of 10 N at 0°, 30° and 45°, only type B OMI model exhibited the total displacement of less than 0.1 mm as presented in table 2, 3 and 4.

Table 2 The Von Mises stress and total displacement compared between type A, B and C OMIs in bone models in three loading force (2, 5 and 10 N) at the direction of 0 degree.

Force at 0° (N)	Max. principal stress (MPa)			Yield strength (MPa)	Total displacement (mm)		
	Type A	Type B	Type C		Type A	Type B	Type C
2	62.30	26.99	84.27	790	0.003	0.0018	0.0063
5	161.60	67.46	195.18	790	0.007	0.0045	0.0159
10	407.80	135.08	380.36	790	0.015	0.0089	0.0286

Bold number = total displacement less than 0.01 mm

Table 3 The Von Mises stress and total displacement of compared between type A, B and C OMIs in bone models in three loading force (2, 5 and 10 N) at the direction of 30 degree.

Force at 30° (N)	Max. principal stress (MPa)			Yield strength (MPa)	Total displacement (mm)		
	Type A	Type B	Type C		Type A	Type B	Type C
2	39.2	27.57	82.77	790	0.002	0.0017	0.0051
5	97.8	68.25	190.78	790	0.007	0.0042	0.0157
10	195.8	136.75	380.22	790	0.0114	0.0085	0.0281

Bold number = total displacement less than 0.01 mm

Table 4 The Von Mises stress and total displacement compared between type A, B and C OMI in bone models in three loading force (2, 5 and 10 N) at the direction of 45 degree.

Force at 45° (N)	Max. principal stress (MPa)			Yield strength (MPa)	Total displacement (mm)		
	Type A	Type B	Type C		Type A	Type B	Type C
2	34.3	24.77	61.16	790	0.002	0.0015	0.0043
5	85.7	61.81	156.94	790	0.006	0.0037	0.0126
10	171.4	123.33	304.44	790	0.012	0.0074	0.0219

Bold number = total displacement less than 0.01 mm

At the direction of 60 degree with the loading force of 2 and 5 N, all of OMI models showed the total displacement of less than 0.01mm. It meant all kinds of OMI could support 2 and 5 N loading forces at 60 degree. In contrast, for 10 N load, only type A and B OMI could tolerance this force at 60° while type C OMI exhibited the total displacement of more than 0.01 mm as presented in Table 5.

Table 5 The Von Mises stress and total displacement compared between type A, B and C OMI in bone models in three loading force (2, 5 and 10 N) at the direction of 60 degree.

Force at 60° (N)	Max. principal stress (MPa)			Yield strength (MPa)	Total displacement (mm)		
	Type A	Type B	Type C		Type A	Type B	Type C
2	27.1	20.59	47.11	790	0.001	0.0012	0.0035
5	67.8	51.28	120.29	790	0.004	0.0029	0.0098
10	135	103.02	237.93	790	0.009	0.0060	0.0171

Bold number = total displacement less than 0.01 mm.

Finally, at 90 degree with the loading forces of 2, 5 and 10 N , three types of OMI models showed the total displacement within limitation (≤ 0.01 mm), so all OMIs could support 10 N loading force with stabilities as presented in Table 6.

Table 6 The Von Mises stress and total displacement compared between type A, B and C OMIs in bone models in three loading force (2, 5 and 10 N) at the direction of 90 degree.

Force at 90° (N)	Max. principal stress (MPa)			Yield strength (MPa)	Total displacement (mm)		
	Type A	Type B	Type C		Type A	Type B	Type C
2	13.7	7.08	10.83	790	0.0003	0.0004	0.0017
5	34.4	19.68	21.78	790	0.0008	0.0010	0.0021
10	74.4	44.50	46.23	790	0.00016	0.0021	0.0028

Bold number = total displacement less than 0.01 mm.

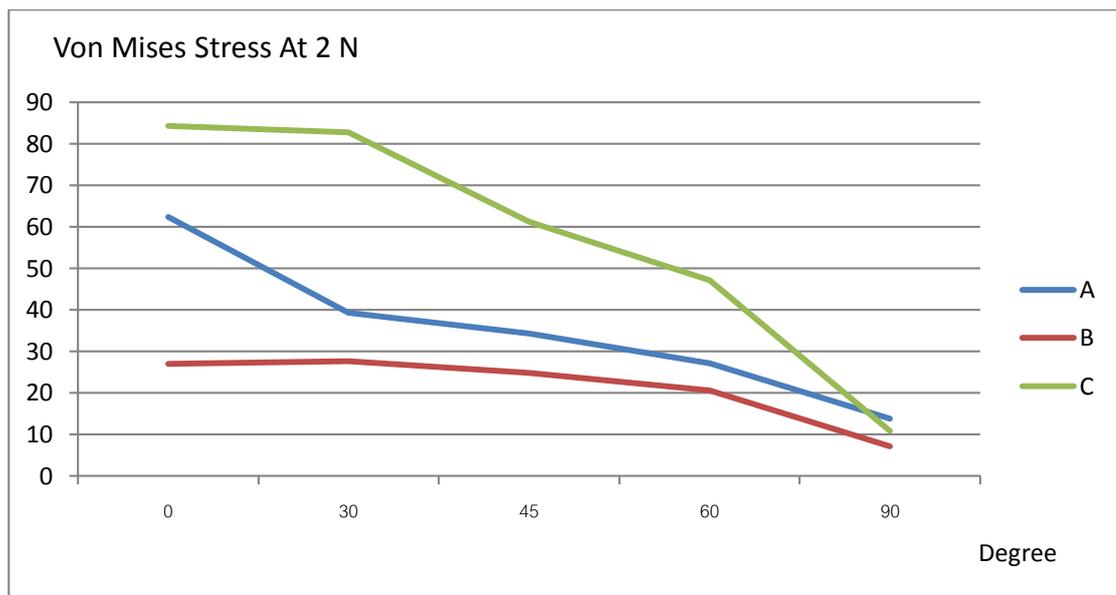


Figure 19 The line graph showed Von Mises Stress of three type OMIs (A,B,C) at the loading force of 2N in five different directions(0°,30°,45°,60°,90°).

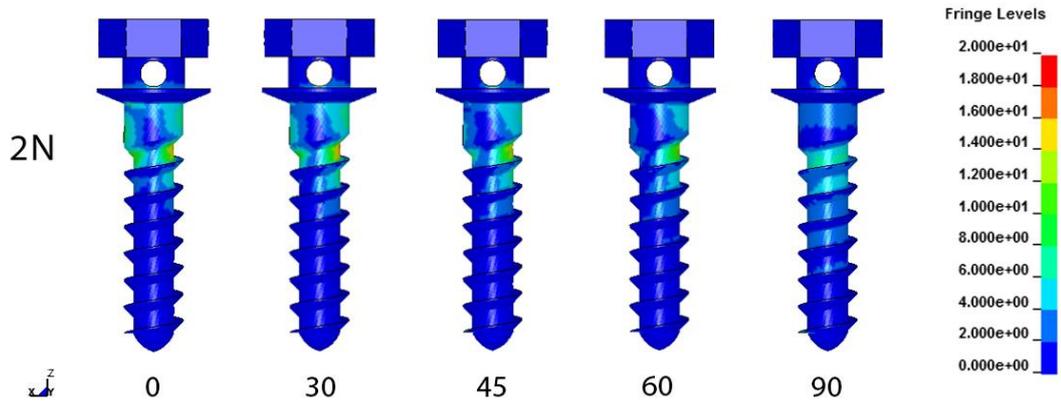


Figure 20 Type B OMI models showed stress distribution pattern at 2 N in five different directions($0^\circ, 30^\circ, 45^\circ, 60^\circ, 90^\circ$). Different colors band represented the stress distribution from lower (BLUE) to higher (RED) value.

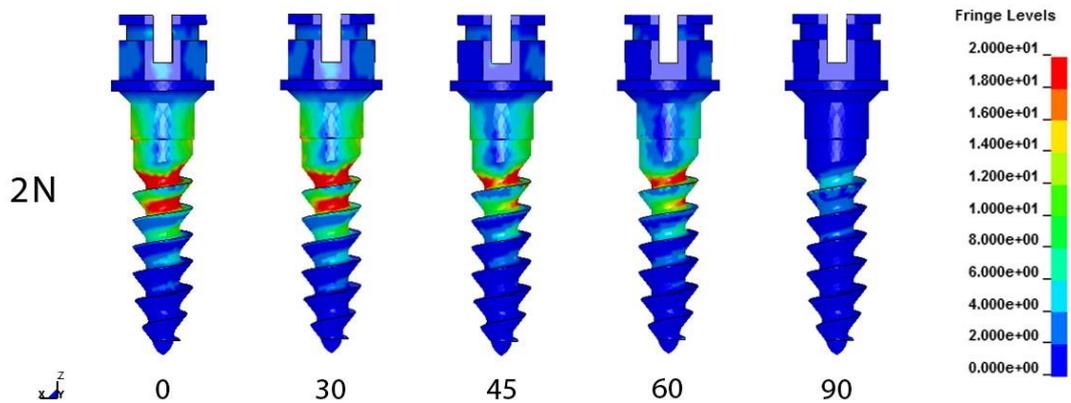


Figure 21 Type C OMI models showed stress distribution pattern at 2 N in five different directions($0^\circ, 30^\circ, 45^\circ, 60^\circ, 90^\circ$). Different colors band represented the stress distribution from lower (BLUE) to higher (RED) value.

From the line graph as shown in figure 19, three types of OMIs (A,B,C) with 2N loading force presented the highest Von Mises Stress at 0° and became less when the direction was tilted to more vertical and the least at 90° . The stress distribution of type B and type C OMI models in the figure 20 and 21, respectively also showed the similar trends as presented in the line graph which showed the most color accumulation at 0° and became less when the direction was change to more perpendicular (90°).

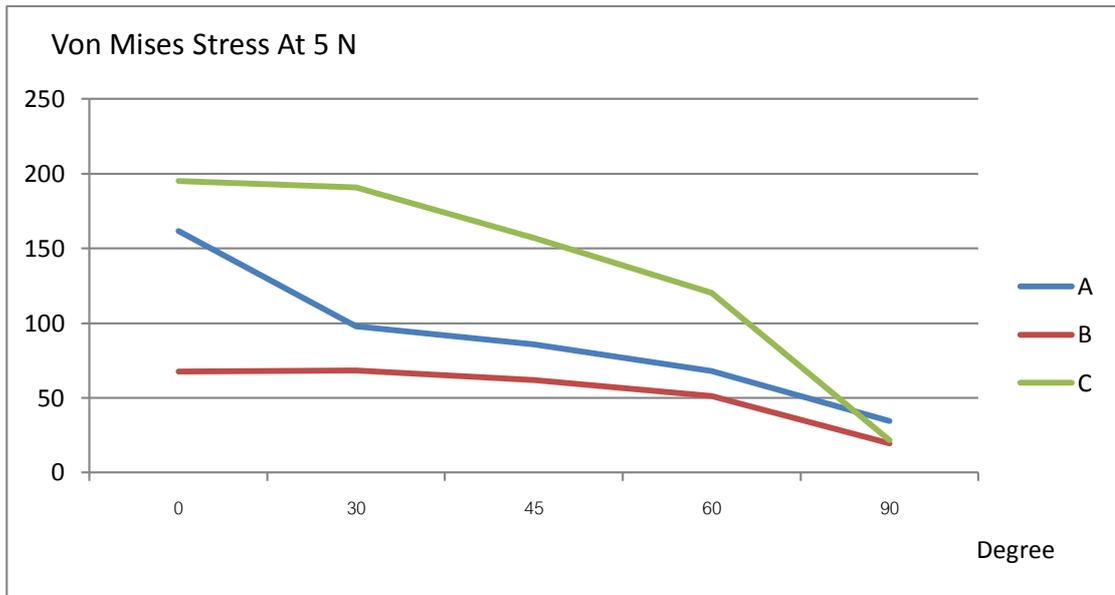


Figure 22 The line graph showed Von Mises Stress of three type OMIs (A,B,C) at the loading force of 5N in five different directions($0^\circ, 30^\circ, 45^\circ, 60^\circ, 90^\circ$).

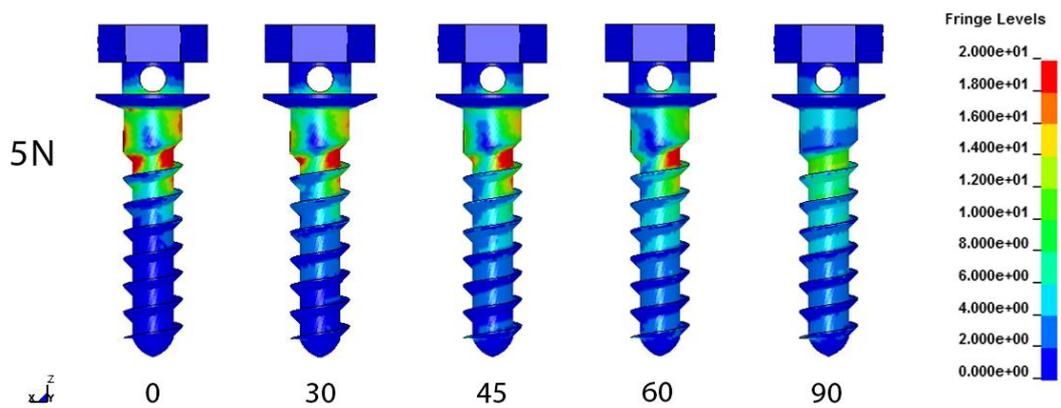


Figure 23 Type B OMI models showed stress distribution pattern at 5 N in five different directions($0^\circ, 30^\circ, 45^\circ, 60^\circ, 90^\circ$). Different colors band represented the stress distribution from lower (BLUE) to higher (RED) value.

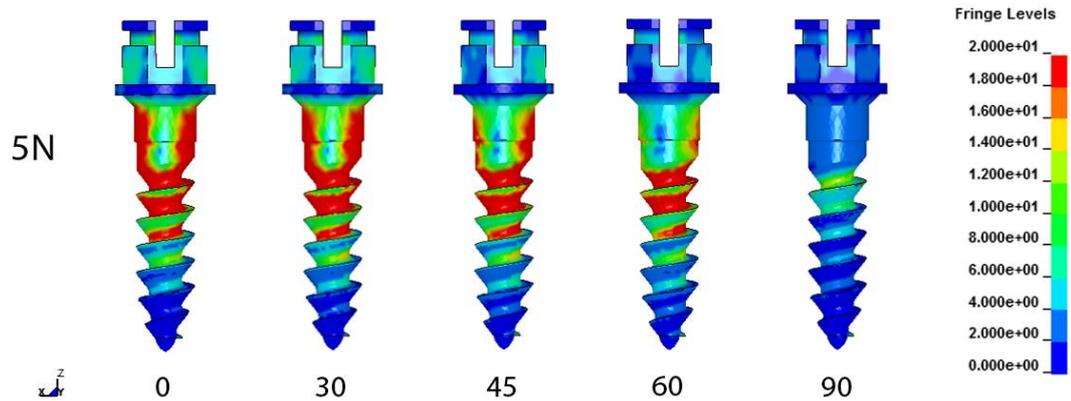


Figure 24 Type C OMI models showed stress distribution pattern at 5 N in five different directions ($0^\circ, 30^\circ, 45^\circ, 60^\circ, 90^\circ$). Different colors band represented the stress distribution from lower (BLUE) to higher (RED) value.

In the figure 22, the line graph showed three types of OMIs (A,B,C) with 5N loading force . It presented the highest Von Mises Stress at 0° until the least at 90° as similar trend as at 2N loading force. Moreover, the stress distribution of type B and type C OMI models in the figure 23 and 24, respectively also showed the similar trends as presented in the line graph. The figures showed the most color accumulation at 0° and became less when the direction was change to more perpendicular (90°), but they showed more color concentration than 2N FEM OMI models. However, type C OMI models obviously presented more stress distribution than type B.

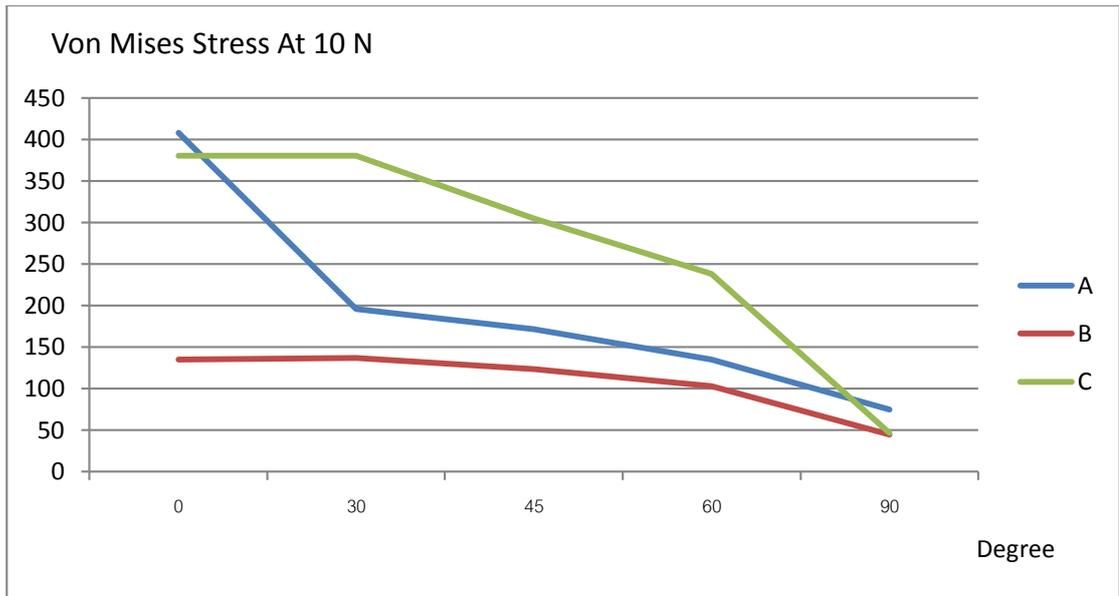


Figure 25 The line graph showed Von Mises Stress of three type OMIs (A,B,C) at the loading force of 10N in five different directions(0°,30°,45°,60°,90°).

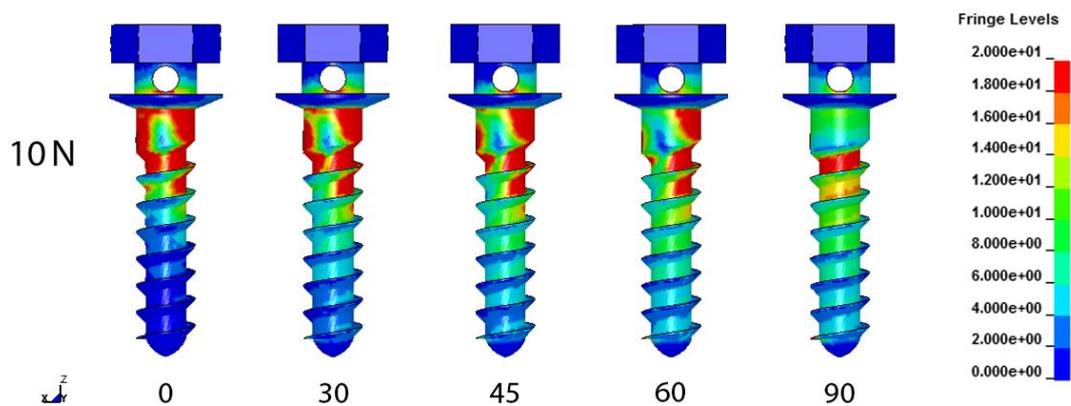


Figure 26 Type B OMI models showed stress distribution pattern at 10 N in five different directions (0°,30°,45°,60°,90°). Different colors band represented the stress distribution from lower (BLUE) to higher (RED) value.

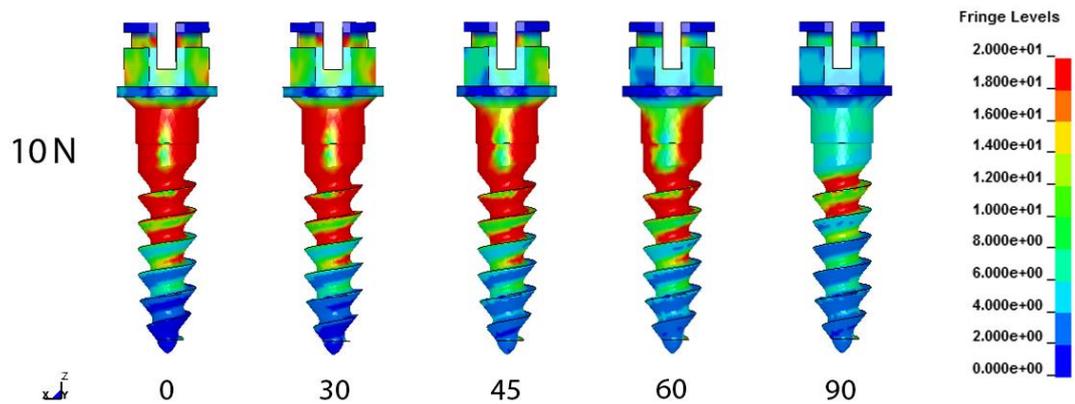


Figure 27 Type C OMI models showed stress distribution pattern at 10 N in five different directions ($0^\circ, 30^\circ, 45^\circ, 60^\circ, 90^\circ$). Different colors band represented the stress distribution from lower (BLUE) to higher (RED) value.

In the figure 25, the line graph showed three types of OMIs (A,B,C) with 10N loading force . It presented the highest Von Mises Stress at 0° until the least at 90° as similar as at 2N and 5N loading force. Also, the stress distribution of type B and type C OMI models in the figure 26 and 27, respectively showed the similar trends as presented in the line graph which showed the most color accumulation at 0° and became less when the direction was change to more perpendicular (90°), but they showed more stress concentration than 2N and 5N FEM OMI models and type C obviously presented the most stress distribution of all models.

However, all types of OMIs were strong enough for supporting forces of 2,5 and 10N in every directions ($0^\circ, 30^\circ, 45^\circ, 60^\circ, 90^\circ$). Type C OMI (Germany) showed the highest Von Mises stress whereas type B OMI (Korea) showed the lowest values in every loading forces. Type A (Thailand), presented the moderate Von Mises stress value comparable to the commercials

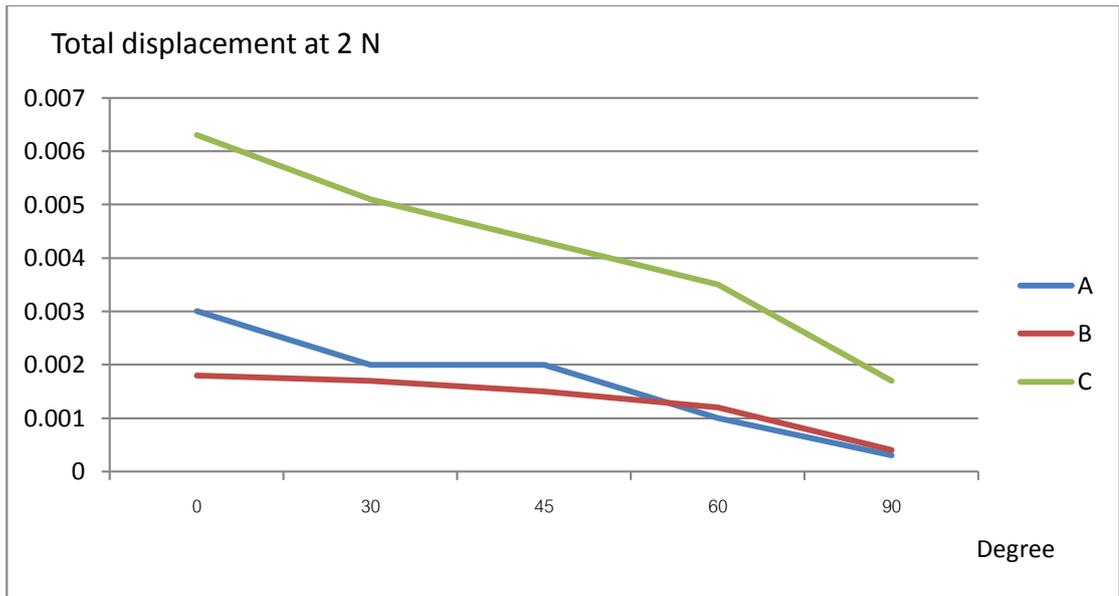


Figure 28 The line graph showed total displacement of three type OMIs (A,B,C) at the loading force of 2N in five different directions(0°,30°,45°,60°,90°).

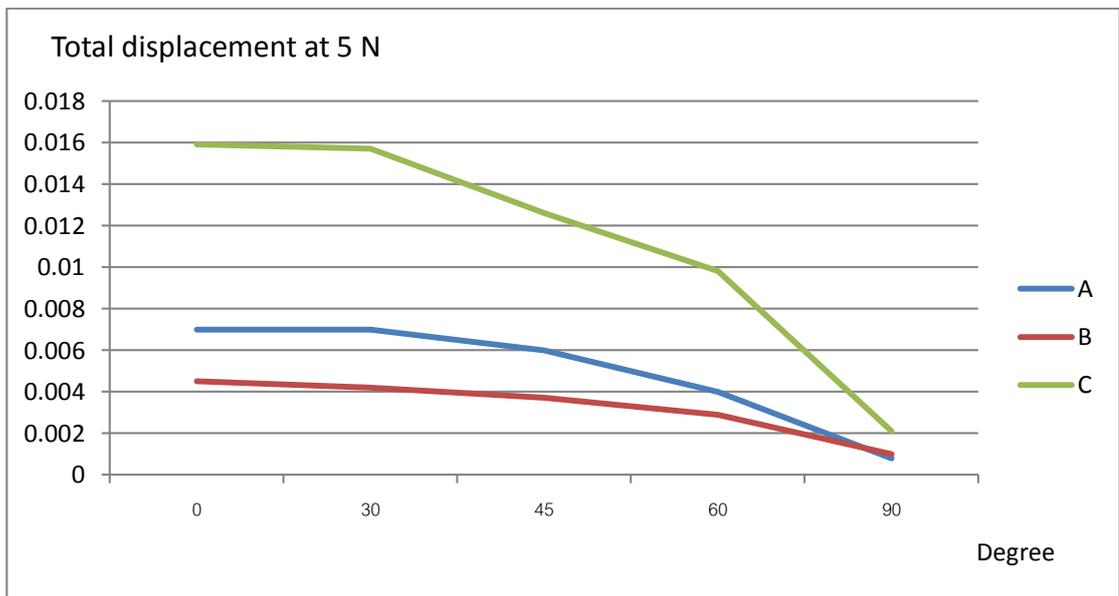


Figure 29 The line graph showed total displacement of three type OMIs (A,B,C) at the loading force of 5N in five different directions(0°,30°,45°,60°,90°).

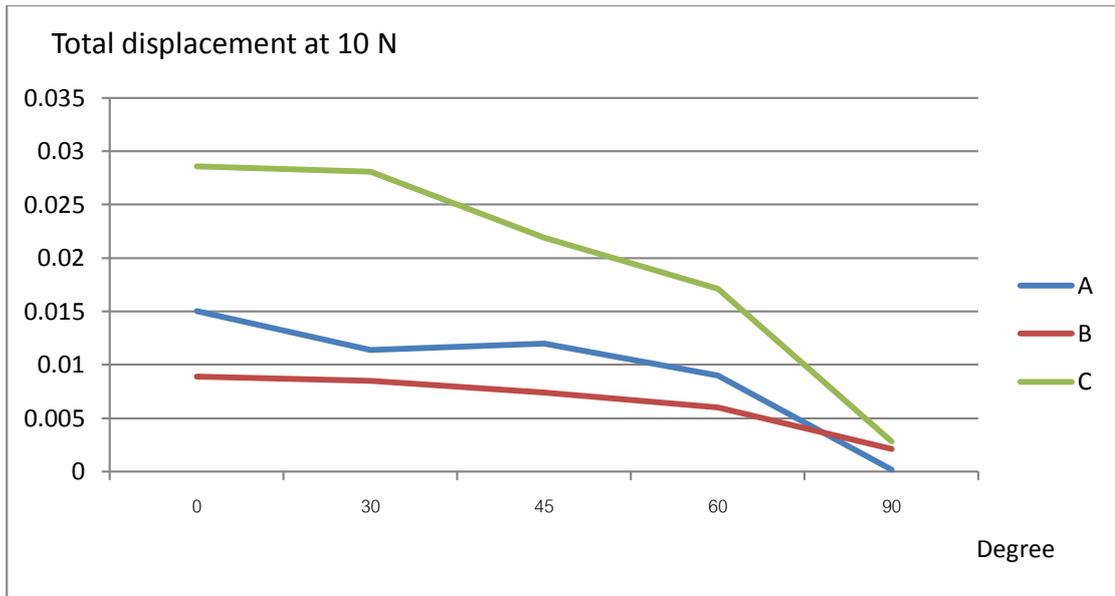


Figure 30 The line graph showed total displacement of three type OMIs (A,B,C) at the loading force of 10N in five different directions(0°,30°,45°,60°,90°).

The total displacement showed different results between the loading forces of 2, 5 and 10N. At 2N the total displacement of three type of OMIs (A,B,C) could support without mobility. For 5N loading force, type A (Thai) and B (Korea) could support in every tested direction (0°,30°,45°,60°,90°) while type C (Germany) could be stable only at directions of 60°and 90°. However, only Korean OMI could bare for 10 N loading force in all directions without mobility while Thai OMI could be comparable to the others.