CHAPTER V
DISCUSSION

Recently, orthodontic miniscrew implants **(** OMIs**)** were used to obtain absolute anchorage and became very popular in clinical orthodontic approaches. The mode of anchorage facilitated by these implant systems has a unique characteristic owing to their temporary use, which results in a transient absolute anchorage. The foregoing properties together with the recently achieved simple application of these screws have increased their popularity, establishing them as a necessary treatment option in complex cases that would have otherwise been impossible to treat **(**Moschos and Tarawneh, 2007**)** . Several designs of OMIs were distributed worldwide with different types, sizes and manufacturers. These are also affected on the stress distribution of OMI and surrounded bone during the orthodontic treatment. Therefore, OMI requires proper designs and characteristics to increase significantly success rate evaluation, as well as, consideration of biomechanics to prevent failure during orthodontic treatment. Complications of stress distribution and OMI mobility could happen after the orthodontic loading which affected stability and safety. In 2005, Motoyoshi and coworkers reported about the biomechanical effects in term of stability of the orthodontic mini-implant with abutment and without abutment design. A traction force of 2 N at 45° to the bone surface was applied to six different OMI models by using finite element method. The results showed no remarkable differences were observed in the stress distribution patterns. However, most of the high-level

stress distribution area was localized at the head of the implant. This report concluded that the existence of the abutment with OMI was significantly useful in decreasing the stress concentration on the surrounding bone, while the effect of thread pitch was uncertain. However, the excessive force of 2 N which was higher than those of generally clinical orthodontic force (25-40 cN per 1 cm^2 of the root area for single-rooted tooth movement) was applied in the study (Motoyoshi et al., 2005) . The optimum force magnitude for orthodontic tooth movement was reported. It was found that no threshold could be defined as the optimum force and the increasing in pressure that will would switch on tooth movement. (Yen et al., 2004). However, a minute force, leading to a minute change in pressure, might be able to switch on tooth movement. This implies that higher forces often used in orthodontic practice do not necessarily produce more efficient tooth movement. On the contrary, they might overload the periodontal tissues and cause negative effects that will hinder tooth movement. Clinically, orthodontic traction angle could be applied to the OMI head differently depending on the direction of tooth movement.

The other interesting factor influenced on OMI stability is the cortical bone thickness (CBT). CBT effected on the stability of orthodontic mini-implants and on the stress distribution in surrounding bone. There were a study in the year 2009 which verified by finite element method that a clinical cortical bone thickness threshold of 1 mm improves the success rate of mini-implants (M. Motoyoshi et al.,2009).

Besides the traction forces on OMIs and CBT, OMI figures is one of the factors influenced the stability of OMI. There was an interesting study in 2009 taken in Germany about the important influential factors affecting the anchorage effectiveness of orthodontic miniscrew implants. Finite element models of sixteen implants from six different manufacturers (American Orthodontics, Dentos, Jeil Medical, Mondeal, IMTEC, Dentaurum) were placed in idealized jaw bone segments using the computer program system (MSC. Marc/Mentat) . OMIs with the length between 6.7-10 mm and diameter between 1.2-2.0 mm were simulated in the thickness of cortex 1 and 2 mm bone models. The Young's modulus of the cancellous bone was various between 100 Mpa and 1 Gpa and the 5 N loading force was applied buccally at the direction of 0°to 45°. In each case, they determined the displacement of the implant head as well as the distribution of stress and strain in the cortical and

cancellous bone. The results showed the displacement varied between 2 microns (Aarhus Mini-Implant 11.6 mm x 2.0 mm, 2 mm cortex) and 20 microns (AbsoAnchor 12.5 mm x 1.2 mm, 1 mm cortex) but most of the implants were varied between 4 and 10 microns. However, the study reported that the stress and strain were reduced by as much as 35% when the buccally tilted loading direction was applied (Stahl et al, 2009). From the study, the displacement or displacement of each OMI was varied among manufacturers due to different designs.

In addition, finite element analysis (FEM) has been proven to be a precise and applicable method for evaluating dental implant systems, included the orthodontic mini implant (OMI). The FEM is a numerical method of analysis for stresses and deformations in structures of any given geometry. The FEM has become one of the most successful engineering computational methods and most useful analysis tool since the 1960s. It is showing overwhelming capability and versatility in its application in dentistry. Future research directions are also recommended with particular emphasis on the stress evaluation and design optimization associated with the implants. (Van Staden RC, Guan H, Loo YC, 2006). Together with Finite Element Analysis (FEM), orthodontic mini-implant (OMI) would be evaluated to be more accurately and more precisely in clinical application.

This research presented and compared the stress distribution and total displacement of three types of orthodontic miniscrew implants **(** OMIs**)** by finite element analysis **(**FEA**)**. The OMI products which were selected to be representative of Asia and Europe were **Dual-Top** (Jeil Medical Corp., Korea) (Figure 9) and **Ortho Easy** (Forestadent, Germany)(Figure 10).

Dual Top system, Jeil Medical Corporation from Korea is one of the most popular in Asian countries. This system has dual head and has various head designs depending on clinical selection. Food and Drug Administration (FDA) approval confirms safely use, additional, each screw design has various lengths and diameter adapting itself in a lot of situations with different inter-radicular distances and soft tissue thickness (http://jeilmed.co.kr).

For the OMI that commonly used in Europe countries is Ortho Easy, Forestadent from Germany. This system was claimed for a special design having sharp cuts for easily insertion with low torsional moment and reduced bone pressure,

resulting in better primary stability. Also, it has various diameters and lengths depending on screw position and mechanical used. International Organization for Standardization (ISO) verified the Ortho Easy system fulfilled the standard requirements in the year 2008 and 2009 (http://www.forestadent.com).

Both OMIs, the Dual Top system, Jeil Medical Corporation from Korea and Ortho Easy, Forestadent from Germany, made from titanium grade 5 (Ti-6Al-4V) . This type of titanium is the most widely used because it is a bio-compatible implant material that can be strengthened with a relatively simple heat treatment to offer very high mechanical properties. This kind of titanium may be heat treated to increase its strength. It can be used in welded construction at service temperatures of up to 600° F. This alloy offers its high strength at a light weight, useful formability and high corrosion resistance. Ti 6AI-4V's usability makes it the best alloy for use in several industries such as aerospace, medical, marine and chemical processing industries (www.supraalloys.com). So, the above material properties are also benefit for OMI to be an anchorage for the orthodontic treatment.

Thai OMI was first introduced by Advance Dental Technology Center (ADTEC) which is a department of National Science and Technology Development Agency (NSTDA), Thailand. The ADTEC together with a professional research team invented a special design of Thai OMI to benefit for orthodontic treatment. Thai OMI was made from titanium grade 23 which is the higher purity version of Ti 6Al-4V. It can be made into coils, strands, wires or flat wires. This material is the top choice for any sort of situation where a combination of high strength, light weight, good corrosion resistance and high toughness are required. It has a superior damage tolerance to other alloys. These benefits make titanium grade 23 the ultimate dental and medical titanium grade. It can be used in biomedical applications such as implantable components due to its biocompatibility, good fatigue strength and low modulus. It can also be used in detailed surgical procedures such as orthopedic pins, screws, cables, ligature clips, surgical staples, springs, bone fixation devices, joint replacements and the orthodontic appliances (www.pmfirst.com). Thai OMI designed by using three dimensions software (3D) with a suitable proportion base on recommendations from professional dentists and orthodontists. At the present time, the research of Thai OMI are developing in a laboratory and preparing for clinical

study to improve to being standardized quality. From this study, Thai OMI could support the loading force up to 5 N in various directions with stability as similar as the standardized commercial OMI. Thai OMI could be a great value for Thai patients to receive non-invasive alternative treatments with security and less expense differed from the conventional orthodontic-surgery treatment. However, there are other factors, such as the biological environment, the bone condition, and oral hygiene of patient, that could effect on success or failure rates.

The results of this study also showed the Von Mises stress in every experimental models less than the yield strength (790 MPa) which were implied that three types of OMI could support the loading force up to 10 N without destruction. For the total displacement, type A,B and C OMI models could be stable with the loading force of 2N (the total displacements < 0.01 mm.) at every tested direction (0˚,30˚,45˚,60˚,90˚). When the loading force increased up to 5N, only type A and B OMI models were in the range of stable limitation. Type A stand for Thai product that could support the traction maximum force of 5N at every tested direction while type C which were represented of Europe product could support only two directions (60˚,90˚). However only type B OMI model could stand for 10N loading at every directions without mobility.

There are also had a study in 2013 about the effects of placement angle and direction of orthopedic force application on the stability of orthodontic miniscrews. An orthopedic heavy force of 800 gf was applied to the heads of the miniscrews in four upward (U0°, U30°, U60°, U90°) or lateral (L0°, L30°, L60°, L90°) directions. The results showed showed a significant increase in maximum Von Mises stress in lateral placement force vectors compared to the perpendicular placement angle to the cortical bone. And the maximum Von Mises stress and displacement of the miniscrew increased as the angle of lateral force increased (L30°, L60°, L90°) (Lee J *et al*., 2013).

Clinically, the application of orthodontic miniscrew implant (OMI) is normally not provide extremely loading force for tooth movement. There was the study in 2003 about the optimum force magnitude for orthodontic tooth movement by reviewing 400 systematic literatures. The research found that three articles reported on premolar tipping using forces from 50 to 200 cN and two articles reported on

molar tipping using forces from 100 to 500 cN in the animal experiment. **(**Ren Y *et al*., 2003**)**. However, the use of ‘‘light’’ forces once became popular on the basis of the classic studies of Storey and Smith (1950s) and Reitan (1960s) in the 1950s and 1960s, respectively. Moreover, it was generally thought that light forces are more efficient and more ‘‘biologic’’ and, hence, less painful **(**Proffit, 1999**)**.

Also, there was a study of Robert WE. and Yoshikawa K. in 1981 in appliances with low load-displacement rates and relatively constant moment and force ratios allow the clinician to take advantage of the type of tooth movement in term of the local stresses and strains which have better effected on cells and the supporting tissues. In addition, the orthodontic force is normally applied in clinical practice for single-rooted tooth movement about 25-40 cN per 1 cm^2 of the root area which is much less force compared to 5N or 10N.

Thai OMI has been developing and improving to be standardization comparable to commercials. From this study, finite element analysis **(**FEA**)** showed the results of Thai OMI in term of Von Mises stress and total displacement slightly inferior to Korean OMI. Although the neck area of Korean OMI was indicated the smallest size compared to three types, it presented the highest stability and support. One important factor was due to the difference of OMI shape designs. Thai and German OMI are conical shape while the Korean OMI is cylindrical shape. There was the study in 2008 compared the stability between cylindrical and conical Type Mini-Implants in terms of the success rate. The samples consisted of cylindrical and conical groups **(**1.6 mm diameter and 6.0 mm length**)** tested in the animal and histomorphometric studies. The conical group showed significantly higher maximum insertion rate and maximum removal rate of stress distribution than the cylindrical group **(**Kima JW et al., 2008). The results of the study supported that the cylindrical shape of OMI related to stability as similar to our study. In addition, designs of thread shape and length, numbers of the thread and the length of the neck of OMI are also important factors effected on OMI success rate. Although the German OMI was shown the risk of mobility due to the conical shape, it had the V-shape thread which was a reverse buttress resisted to the loading force. Because the finite element method (FEM) of our study was static characteristic which showed the results within limitation so, the advance dynamic FEM could be applied for the further study to evaluate in other aspects. Insertion and

removal torques of OMIs could also induced the stress distribution and total displacement that should be consideration for OMI strength and stability. In our study, finite element method (FEM) calculated within the static limitation in term of the stress distribution and the total displacement only when OMIs were seated into the bone model. Thai OMI was expected to be strong and stable comparable to commercials so, the advance dynamic FEM should be applied for the further study to evaluate in other aspects. Also, the next improvement of Thai OMI could take an interested in the animal experiment to estimate the relation between OMI stability and biological factor