OCCLUSAL FORCE DISTRIBUTIONS AND DENTAL DISCLUSION TIME IN ANGLE'S MALOCCLUSIONS: AN EVALUATION BY THE T-SCAN III SYSTEM

TITIRAT CHUTCHALERMPAN

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Oral Defense Committee

....Chair
(Associate Professor Chidchanok Leethanakul, Ph.D.)

....Advisor
(Associate Professor Thosapol Piyapattamin, Ph.D.)

....Co-advisor
(Assistant Professor Jittima Pumklin, Ph.D.)

....Internal Examiner
(Praweena Sopapornamorn, Ph.D.)

Approved

....
(Professor Paisarn Muneesawang, Ph.D.)
Dean of the Graduate School

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Titirat Chutchalermpan

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Author	Titirat Chutchalermpan
Advisor	Associate Professor Thosapol Piyapattamin, Ph.D.
Co-advisor	Assistant Professor Jittima Pumklin, Ph.D.
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ABSTRACT

The main objective of this study was to compare the occlusal force distributions along the maxillary dental arch at its MIP and the DT during excursions among Angle's malocclusions. One hundred healthy subjects. According to Angle's malocclusions, those subjects were divided four groups into Class I, Class II division 1, Class II division 2 and Class III. By using T-Scan III system, all subjects were recorded the DT (sec) and occlusal force distribution (%). A one way ANOVA was used to compare among malocclusion types, followed by a post hoc test ($P < 0.05$). No significant difference in percentage of occlusal force distribution among malocclusion type. Class III malocclusion has significant difference in the disclusion time, when compared with the other groups. In each malocclusion, the percentage of occlusal force were 8.93±6.31, 9.44±6.75, 13.07±8.35, and 10.58±8.46 at the anterior region. They were 24.74±9.42, 24.93±7.25, 22.93±9.92, and 27.78±11.51 at the premolar, and 66.42±12.63, 65.80±11.66, 63.87±16.20, and 61.65±15.33 at the molar regions. In the respective malocclusion types, the disclusion time were 2.08±0.65, 2.13±0.74, 2.12±0.72, and 3.19±1.34 seconds at the left excursion. They were 2.15±0.94, 2.58±1.16, 2.37±1.07, and 3.28±1.25 seconds at the right excursion, and 1.88±0.99, 2.08±1.11, 2.07±0.68, and 3.01±1.53 seconds at the protrusion. In each excursion, Class III malocclusion had significant differences of disclusion time, when compared with other Class. In all malocclusions, the posterior region was the area with most force distributions. In each

malocclusion type, there were significant differences in the force distributions among molar, premolar, and anterior regions. Relative occlusal force distributions in each region were not significantly different among the malocclusions. Disclusion time in each excursive movement was significantly different among the malocclusions. Our study, the subjects with Class III malocclusion had the longest disclusion time in all excursive movement.

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CHAPTER I

INTRODUCTION

Background and rationale for the study

A good occlusion is one important factor in the dental therapy, particularly an orthodontic treatment. An establishment of functional occlusion and stability, a promotion of a good periodontal health, and a construction of esthetics are its main objectives. At the completion of an orthodontic treatment, a patient should possess simultaneous contacts of all teeth with a good timing and an equal intensity of masticatory force distribution in all directions of mandibular movement. In addition, there should be a canine-protected occlusion with a less load on the anterior than the posterior teeth [1-2]. Some occlusal problems are documented to result in a muscular disharmony that leads to temporomandibular disorder (TMD) [3-4]

TMD represents multifactorial causes not yet fully understood. It is usually related to trauma, stress, parafunctional habits, occlusal changes, or masticatory disturbances. Almost all of the patients with internal joint pathology, muscle spasms, or psychogenic problems also suffer from TMD [5-6]. According to TMD prevalence, the masticatory system's adaptive capacities are influenced by several factors [7-8].

One area of the greatest debate has been related to an association between TMD and occlusal factors as a causal role [9]. It has been documented that the masticatory muscles' electrical signal recordings are dependent on some occlusal features [10]. In addition, functional jaw movements are closely associated with the dental occlusions [11].

Some symmetrically bilateral actions of masseter and anterior temporal muscles have been recognized in those with an adequate occlusion and without dysfunction [12]. Some occlusal aberration has been reported to disrupt some harmoniously functional patterns of the masticatory pattern. Whether this becomes disorder is believed to depend upon one's tolerance level [13]. Some associations between muscular imbalances and the development of TMD signs and symptoms have been documented [8,14-15]. Premature contacts, some interferences (balancing or working side), and the loss of posterior teeth are also reported to cause such imbalances

[11,16-18]. A maladaptive occlusion is likely to be a significant factor in TMD. It may be involved in masticatory system recognizing the effect of mechanical stress [19-20]. Multi-directional muscular loading forces to an increased temporomandibular joint (TMJ) loading are the results of degenerative TMJ diseases. Multiple dental and articular constraints' selective actions are influenced by load's duration and degree [9].

TMD has been stated to relate to some occlusal changes. They include premature occlusal contacts [18,21-22], lack of anterior guidance [4], balancing side interference [23], Class II [4,22,24-26] and Class III [22,27] sagittal relationships, anterior open bite [22,25,27], crossbite [27], an over +5.0-mm-overbite or overjet [28], an over 2- to 4-mm-centric relation discrepancy to the usual maximum intercuspation position (MIP) [13,23,28], and an over four number of missing posterior teeth [13,28]. Several studies have suggested some positive associations between TMD and the mentioned causes, whereas an equal number has found minimal or no association [13,29-30]. Some recent reports on TMD symptoms demonstrated a positive relationship with some parafunctional habitн [8,31-33], together with a non-significant association with some morphologic occlusion or functional occlusal factors [9,20]. Hence, TMD-static occlusal factor relationships have never been reported [13,33-34].

In some orthodontic researches, a patient's functional occlusion is accessible by a T-Scan III system. It records the inter-arch contacts' static and dynamic qualities, are real-time recognized, and can be preserved for future comparisons [35-37].

Disclusion time (DT) is the time for reaching the anterior teeth, post-departure from MIP during a mandibular excursion, and it is revealed that the longer the DT observed electromyographically, the longer the masseter muscle excessively firing [38]. Some DT adjustment to less than 0.4 sec per excursion prevents an increased excessive muscular forces from excessive loads at posterior teeth, periodontium, and TMJ [35,39-40]. TMD-patients have some bilaterally asymmetrical occlusal forces than the non-TMD ones. In addition, those with TMD have a prolonged occlusion time and DT [41-44].

By the use of a relationship between permanent first molars as suggested by Angle, malocclusions are classified into Class I, Class II division 1, Class II division 2, and Class III [32,45]. Previous studies have revealed some relationships between malocclusions and TMD [4,22,24-28]. However, such associations are not clearly proved. Due to an imbalance of occlusal force distribution between MIP and prolonged

DT during lateral excursion, different Angle's classifications probably affect the performance of occlusion.

A study of distribution of occlusal force and DT among different malocclusion types is worth reminding an orthodontist to increase an awareness in an existence of malocclusion, if any, during a corrective orthodontic treatment. In those with some different malocclusions, there have been some data on the durations of DT during left and right excursive movements, but none on those during the protrusive position. Due to some differences among the methods used in each study, the results from previous investigations have neither been intermingled nor reported. In addition, none has provided the comparisons of the occlusal force distribution and DT among all of Angle's malocclusion types.

Hence, the present clinical study's objectives are to compare and evaluate the occlusal force distributions along the maxillary dental arch at its MIP and the DT during mandibular protrusion and lateral excursions among the subjects with different Angle's malocclusions by using a T-Scan III system.

Research questions

1. By using the T-Scan III system, is there any difference in the occlusal force distributions among Angle's malocclusions (Class I, Class II division 1, Class II division 2, and Class III malocclusion)?

2. By using the T-Scan III system, is there any difference in DT during mandibular protrusion and lateral excursions among Angle's malocclusions (Class I, Class II division 1, Class II division 2, and Class III)?

Research objectives

1. To compare the occlusal force distributions along the maxillary dental arch at its MIP among Angle's malocclusions (Class I, Class II division 1, Class II division 2, and Class III) by using the T-Scan III system

2. To compare the DT during mandibular protrusion and lateral excursions among Angle's malocclusions (Class I, Class II division 1, Class II division 2, and Class III) by using the T-Scan III system

Scopes of the study

This clinical study is designed to compare and evaluate the occlusal force distributions along the maxillary dental arch at its MIP and the DT during mandibular protrusion and lateral excursions among Angle's malocclusions (Class I, Class II division 1, Class II division 2, and Class III) by using the T-Scan III system.

Independent variables:

Untreated Angle's malocclusions (Class I, Class II division 1, Class II division 2, and Class III malocclusion)

Dependent variables:

Occlusal force distribution, DT

Location:

3rd floor, NSU 03 Building, Faculty of Dentistry, Naresuan University

Keywords

Angle's classification; disclusion time; occlusal force distribution; T-Scan III

Research hypotheses

1. By using the T-Scan III system, there is some significant difference in the occlusal force distributions among Angle's malocclusions (Class I, Class II division 1, Class II division 2, and Class III malocclusion)?

2. By using the T-Scan III system, there is some significant difference in the DT during mandibular protrusion and lateral excursions among Angle's malocclusions (Class I, Class II division 1, Class II division 2, and Class III)?

CHAPTER II

LITERATURE REVIEW

Some orthodontic treatment objectives are consisted of a creation of facial and dental esthetics, a generation of stable and ideal static and functional occlusions, an establishment of dental stability, and an improvement of periodontal health [45]. Dental occlusions can be classified by using the mandibular positions (Table 1) [32,46-47], the relationships between permanent first molars (Table 2) [45,47], and the organizations of occlusions (Table 3) [32,45].

Ideal occlusion concepts are related to esthetics and a physiologic occlusion including some disharmonious functions, the masticatory system's stability, and the masticatory system's harmonious neuromusculatures [47-48]. Normal occlusion concepts imply a non-disease situation and include some anatomically acceptable values and a physiological adaptability [47-48].

Classifications of malocclusions

Classifications of malocclusions are the descriptions of dento-facial deviations, in accordance with a common characteristic or a norm. Based on each researcher's experiences, various classifications are proposed and are dependent upon whatever found to be clinically relevant [45].

Angle's concept of static occlusion [45]

According to Angle's classification, molar relationships are defined by using the mesio-distal relationship of the teeth, dental arches, and jaws (Table 2). In this concept, the permanent maxillary first molar is considered the jaws' fixed anatomical point and the occlusion's key.

Andrew's six keys of normal occlusion [49]

The concept of an ideal static occlusion has been redefined by Andrews into six keys as follows:

Key 1 (molar relationship): The distal surface of the permanent maxillary first molar's disto-buccal cusp makes contact and occludes with the mesial surface of the permanent mandibular second molar's mesio-buccal cusp. The permanent maxillary first molar's mesio-buccal cusp tip points at the permanent mandibular first molar's mesio-buccal groove.

Key 2 (crown angulation; the mesio-distal tip): The gingival portion of each crown's long axis is distal to the incisal one, in spite of some variations between the tooth types.

Key 3 (crown inclination; labio-lingual or bucco-lingual inclination): Crown inclination is referred to the labio- or bucco-lingual inclination of a crown's long axis and is an angle between the line tangential to the clinical crown's mid-facial surface.

The maxillary incisors' clinical crowns are so placed that their incisal are labial to their gingival portions. In all other crowns, their labial or buccal surfaces' occlusal portions are lingual to their gingival ones. In the maxillary molars, their lingual crown inclinations are slightly more pronounced, when compared those of the canines and premolars. In the mandibular ones, their lingual inclinations are progressively increased from the first premolars to the third molars.

Key 4 (rotation): Each tooth shows no rotation.

Key 5 (space): No space between teeth and contact points/areas are tight.

Key 6 (occlusal plane): The plane of occlusion can be varied from generally flat to a slight curve of Spee.

Roth' s keys of functional occlusion [50]

The functional aspects of the occlusion have been presented by Roth as being fundamental for completion of the orthodontic cases. They are as follows:

1. MIP (or intercuspal position, ICP) and centric relation (CR) position (or retruded contact position, RCP) are coincident.

2. In CR position, all posterior teeth must present axial occlusal contacts and the anterior teeth must maintain a 0.0005-inch-distance between them.

3. During lateral excursion, the canines must disclude the posterior teeth (canine guidance).

4. During protrusion, the maxillary and mandibular anterior teeth must occlude among each other, aiming at discluding all posterior teeth (immediate anterior guidance).

5. No interference must be present on the balancing side.

Mandibular movements

Several types of mandibular movements are observable and each possesses a unique pattern (Table 4) [46,48].

Table 1 Classifications of occlusions based on the mandibular positions [32,46,48]

Occlusion type	Characteristics	Definition
Habitual occlusion/ Maximum intercuspal position (MIP)/ Intercuspal position (ICP)	Tooth-determined position	Complete intercuspation of the opposing teeth independent of condylar position, sometimes referred to the best fit of the teeth, regardless of the condylar position
Centric occlusion (retruded contact)	Joint-determined position	Occlusion of opposing teeth when the mandible is in centric relation. This may or may not coincide with the maximal intercuspal position
Eccentric occlusion	Lateral occlusion	Contact between opposing teeth when the mandible is moved either right or left from the mid-sagittal plane
	Protruded occlusion	Occlusion of the teeth when the mandible is protruded (mandibular position is anterior to centric relation)
Centric relation	A maxillo-mandibular relationship independent of tooth contact, where the condyles articulate in an antero-superior position against the posterior slopes of the articular eminences. In this position, the mandible is restricted to a purely rotary movement from this unstrained and physiologic maxillo-mandibular relationship. The patient can make vertical, lateral, or protrusive movements. It is a clinically useful and repeatable reference position.	

Table 2 Classifications of occlusions based on the relationships between permanent first molars [32,45]

Occlusion type	Definition	
Class I (neutro-occlusion)	Mesio-buccal and mesio-lingual cusps of the maxillary first molar occlude in the buccal groove and with the fossa, respectively, of the mandibular first molar, when the jaws are at rest and the teeth are approximated in centric occlusion.	
Class II (disto-occlusion)	Mesio-buccal cusp of the maxillary first molar occludes in the space between mesio-buccal cusp of the mandibular first molar and distal aspect of the mandibular second premolar. In addition, mesio-lingual cusp of the maxillary first molar occludes mesially to mesio-lingual cusp of the mandibular first molar.	
	Division I	Bilateral distal retrusion with a narrow maxillary arch, protruded maxillary incisors, and an increased overjet
	Division II	Bilateral distal retrusion with a normal or a square-shaped maxillary arch, retruded maxillary central incisors, labially malposed maxillary lateral incisors, and a deep bite
Class III (mesio-occlusion)	Mesio-buccal cusp of the maxillary first molar occludes in the space between the distal cusp's distal aspect of the mandibular first molar and the mesial cusp's mesial aspect of the mandibular second molar.	

Table 3 Classifications of occlusions based on the organizations of occlusion [32,45]

Occlusion type	Position	Definition
Mutually protected occlusion	Maximum intercuspation	Posterior teeth provide maximum occlusal loading and protect anterior teeth from heavy loading.
	Protrusion	Anterior teeth occlude with a result of a protection for or a disclusion of posterior teeth.
	Lateral excursion	Teeth on the working side contact and provide a protection for or a disclusion of those on the non-working side.
Canine-guided or -protected occlusion	During a lateral movement, only canine on the working side comes into contact with its opposing tooth, causing a disto-occlusion of all posterior teeth.	
Group function occlusion	During a lateral movement, canine and one or more adjacent pairs of posterior teeth on the working side are in simultaneous occlusal contacts.	

Table 4 Descriptions of the types of mandibular movements and their related terminology [46,48]

Type/Terminology	Definition
Hinge movement	Movement in space characterized by two divergent points moving around a central axis of rotation
Translatory movement	Movement in space characterized by a linear motion without axis of rotation. It may follow a straight or a curved path.
Lateral excursion	Forward, inward, and downward translation of the contralateral condyle. Ipsilateral condyle rotates around an axis.
Working side	Lateral segment of the dentition toward which the mandible is moving during lateral excursion
Non-working side	The side opposite to the working side during lateral excursion of the mandible
Anterior guidance	As influenced by the overjet and the overbite As determined by the maxillary anterior teeth's palatal surfaces and the mandibular incisors' incisal edges

Table 5 Definitions of postural rest position and maximum intercuspation [32]

Position	Definition
Postural rest position	Mandibular position at which the oro-facial system's synergists and antagonists are in their basic tonuses and are balanced dynamically. A minimal amount of elevator muscle activity is needed to maintain the mandible in the position.
Maximum intercuspation	Occlusal position of the mandible in which the teeth's cusps of both arches fully interpose themselves with the cusps of those of the opposing arch

Functional analyses are important for an identification of the malocclusions. They include some evaluations of the postural rest position and MIP (Table 5) [32], together with the sagittal, vertical, and frontal paths of mandibular closures from postural rest position to centric occlusion (Table 6) [32].

Table 6 Paths of mandibular closures in sagittal, vertical, and frontal planes [32]

Plane	Path of mandibular closure	Malocclusion observed
Sagittal	Pure rotational movement without a sliding component	True Class II/Class III (No functional disturbance)
	Forward path of closure (rotational movement with anterior sliding movement)	Functional protrusion Class II/pseudo Class III
	Backward path of closure (rotational movement with posterior sliding movement)	Class II division 2 (Mandible slides backward into a posterior occlusal position, due to premature contact and retroclined maxillary incisors) Pronounced mandibular prognathism (Mandible may slide posteriorly into the position of MIP, and it is marked the true sagittal dysplasia.)
Vertical	True deep overbite	Infraocclusion of the molars
	Pseudo-deep bite	Over-eruption of the incisors
Frontal	Laterognathy or true crossbite	Mandibular and facial midlines non-coincide in rest and in occlusion.
	Laterocclusion	Mandibular and facial midlines coincide in rest position, but mandible is deviated in occlusion, due to tooth interference leading to non-coinciding midlines.

Masticatory system and performances

Functional and structural disturbances in any component of the masticatory system viewed as a biological one are detectable by some disorders in one or more components of the system [51]. With its wide range of adaptive modalities, the system's adaptations can be functional and/or structural and may respond to transient and/or permanent demands [20,51].

Some pathogeneses of muscular performances associated with fatigue, discomfort, and pain in mandibular elevator muscles are influenced by the dental occlusions. The elevator muscles are controlled by some feedbacks from periodontal mechanoreceptors [52-54], causing the occlusion system to be efficient by an occlusal stability. During biting and chewing, the elevator muscles in those with a good occlusal support, particularly from the posterior teeth, are activated with a high degree of force and masticatory efficiency [55]. An extent of occlusal contacts has clearly affected the muscular activity, bite force, jaw movement, and masticatory efficiency. In addition, some reduction of occlusal support is a risk factor in TMD development [16].

TMD

The etiology of TMD is complex and multifactorial and numerous factors can contribute to TMD. Trauma, deep pain input, parafunctional activities, emotional stress, and some occlusal conditions are five major factors associated with TMD [32]. In addition, some occlusal problems are related to TMD signs and symptoms (Table 7), possibly affecting masticatory functions and favoring functional asymmetry of the stomatognathic system [20].

Some chewing functions influence the alteration, remodeling, and development of the stomatognathic structures and load distributions. A unilateral chewing implies some asymmetrical joint dynamics and load distributions [56]. More TMD signs and symptoms have been reported in people with a predominantly one-sided chewing habit [57], and some similar results between unilateral chewing and TMJ disturbances have been documented [58].

Table 7 Reports on the occlusal factors contributing to TMD signs and symptoms

Occlusal factors	Investigators, year
Class II	Egermark-Eriksson et al., 1983; Seligman et al., 1988 Seligman et al., 1989; Henrikson et al., 1997; Selaimen et al., 2007
Class III	Egermark-Eriksson et al., 1983; Gazit et al., 1984; Thilander et al., 2002
Premature occlusal contacts	Egermark-Eriksson et al., 1983; Kirveskari et al., 1992; Learreta et al., 2007
Lack of anterior guidance	Selaimen et al., 2007
Balancing side interference	Landi et al., 2004
Anterior open bite	Egermark-Eriksson et al., 1983; Gazit et al., 1984 Seligman et al., 1989; Thilander et al., 2002
Crossbite	Gazit et al., 1984; Thilander et al., 2002
Overjet/overbite > +5.0 mm	Pullinger et al., 1993; Thilander et al., 2002
Sliding in centric	Ramfjord, 1990; Landi et al., 2004
Missing posterior teeth ≥ 5	Ramfjord, 1990; Landi et al., 2004

Relationships between malocclusions and masticatory muscles

Bioelectrical activities of some masticatory muscles recorded by EMG and bite force upon the muscles' maximal voluntary contractions have been reported. A correlation of disorders between the occlusion and the oro-facial muscles' functions has also been available [59]. Some clinical relationships between the malocclusion types and the masticatory muscles' activities have also been investigated. Patients with a deep bite have some significantly higher muscular activities than those with other malocclusion types. In patients with an edge-to-edge bite, their temporalis muscles' activities on the balancing side are higher than those on the working side [60]. During mastication and deglutition, some significant differences of the masticatory muscles' activities between patients with Class II division 2 and those with Class III have been revealed [61]. When compared among patients with different skeletal profiles, the masseter and the anterior temporalis muscles' postural activities are highest in Class III malocclusion, with some similarities between Class I and Class II malocclusions. During swallowing, masseter muscle activities in Class III are highest and no difference in anterior temporal muscle activity is detectable between Class I and III malocclusions. During maximal voluntary clenching, the activities are not different among malocclusion types [62-63]. Moreover, some impaired activities of temporalis and masseter muscles have been reported in patients with Class II division 1 malocclusion [64].

Relationships between malocclusions and TMD

The relationship between malocclusion and adaptive functions to TMD is understood much better now than only a few years ago. Despite some report on a relationship between the stomatognathic system and some cranio-cervical muscles, their clear association has not been established [18]. The pain may result from some pathologic changes within TMJ, but more often is caused by muscular fatigue and spasm. Muscular pain is almost always correlated with a history of clenching or grinding the teeth (as a response to some stressful situations) or of constantly posturing the mandible to an anterior or a lateral position [3]. Some investigators have suggested that even minor imperfections in the occlusion serve to trigger clenching and grinding activities [3]. However, those with poor occlusion have shown no problem with muscular pain when stressed, but are reported to develop symptoms in other organ systems. This implies no association between malocclusion and TMD [3].

Human proprioceptive and periodontal inputs are changed by some malocclusions [65]. An alteration of the masticatory muscles' activities possibly modifies TMJ movement patterns [66]. The masticatory movements' wide variabilities among individuals suggests some different effects of peripheral impulses on the masticatory movements. However, the occlusal variables may or may not influence the jaw movements' motor responses during mastication. Such response is dependent on the masticatory movement's pattern developed by a person [20].

Etiology of masticatory muscles' excursive hyperactivity has been theorized that the elevated levels of excursive muscle activity are instigated from prolonged excursive molar tooth contacts, resulting in prolonged compressions of the periodontal mechanoreceptors [41]. The proposed mechanism has suggested that the longer the excursive interference time, the longer the ligament compression time, and the longer the activated masticatory muscles' contraction time [35].

Bite forces and their measurements

Biting under some conditions of the right-left imbalances and the occlusal contact discrepancies activate some muscles that should not be activated [18]. During a full closure to interdigitation, the interdental force is distributed down the posterior teeth's long axes with a total 50/50 right-to-left force balance [67]. In addition, the bite forces are dependent on the occlusion types. Patients with normal occlusion have been shown to have a greater one, followed by those with Class I, Class II, and Class III malocclusions, respectively [68].

Facial morphology is related with occlusal forces and its three types (long, average, and short) are documented are documented. The long type has an excessive vertical facial growth and an anterior open bite, while the short one a reduced vertical growth, a deep anterior overbite, and some reduced facial heights [69]. Bite force is explained to reflect the mandibular lever system's geometry. With a more vertical ramus and an acute gonial angle, the elevator muscles exhibit some greater mechanical advantages [70]. Masseter muscles are thicker in subjects with short face than those with normal or long ones. Hence, it seems that the short-faced people may exhibit a stronger bite force [71]. In addition, the long-faced people have some significantly less occlusal forces during maximum effort, simulated chewing, and swallowing than do individuals with normal vertical facial dimensions. The bite force in the molar region is twice as great in the subjects with normal face as in those with the long one. Moreover, those with the short type could generate even higher forces than those with the normal one [3].

Functions of occlusion can be directly and indirectly evaluated by various methods (Table 8), thus causing some different occlusal parameters. They include maximum bite forces, occlusal forces, and occlusal contact areas [72]. With the use of some transducer, bite fork, and bite force dynamometer, maximum bite forces can be measured. An alternative method is some indirect evaluations of the bite forces by employing other physiologic variables functionally related to the force productions. Surface EMG is useful for a functional study of occlusal dysfunctions [44,61], due to the results of some investigations showing a linear relationship between EMG activity potentials and direct bite force measurements, particularly at a submaximal level [73]. Transmission of the sound vibration to the chin (through teeth, TMJ, and muscular pathways) has been reported to illustrate the occlusal force [74]. Such force can also be recorded by a Dental Prescale System, 50H type R (Fuji Film, Tokyo, Japan) [75]. An articulating paper has been used for the record of occlusal contacts' mean number in patients with Class I and Class II Division 1 malocclusions [76], despite the results of no inter-group significant difference. Utilized as a tool for some quantitative comparisons of the occlusal contacts, some three-dimensional digital models have revealed some better posterior contacts in patients with Class I than those with Class II molar relationship [72].

Table 8 Direct and indirect records of the bite forces and the devices used as reported by some investigators [69-70]

Method of records	Device used	Investigators, year
Direct	Bite fork	Helkimo et al., 1977 [77]
		Kiliaridis et al., 1993 [78]
	Strain gauge transducer	Lindauer et al., 1993 [79]
		Braun et al., 1996 [80]
	Gnathodynamometer	Ortug, 2002 [81]
	Foil transducer	Burke et al., 1973 [82]
	Pressurized rubber tube	Braun et al., 1995 [83]
	Pressure-sensitive sheet	Sondang et al., 2003 [84]
	Force-sensing resistors	Fernandes et al., 2003 [85]
Indirect	Surface EMG	Ferrario et al., 2004 [73]

Molars generate greater maximum forces than anterior teeth [86-87]. The largest maximal voluntary bite force is developed in the vertical direction. In oblique directions, the largest force is exerted with a posteriorly directed effort corresponding to about 90%, medially, 80% laterally, and 70% anteriorly of the maximal bite force perpendicular to the maxillary teeth's occlusal plane [88]. At the natural dentition's molar region, a unilateral maximal bite force is approximately 300-600 Newton [89]. The bite force's direction, not magnitude, determines the pattern of jaw-closing muscles' activities [90]. All traditional occlusal indicators' main limitations are their incapability of demonstrating different bite force level in each teeth, the occlusal contacts' sequences, or DT [91-92]. However, a T-Scan system overcomes such limitations.

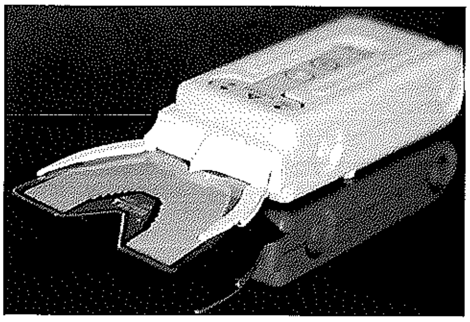


Figure 1 A T-Scan III system for the computerized occlusal analyses of force, time, and location

Source: Kim, J. H. [93]

T-Scan system and its advantages over other devices

Unlike other non-digital devices, a T-Scan system provides information on occlusal measurements and evaluations. When some repeated measurements in the same subject are evaluated, no significant difference among the results is detected, thus illustrating the system's sufficient validity and reproducibility [91,94-95]. Currently, T-Scan III system has been the newest version for an analysis of a dynamic occlusion with a great precision. Some computers have been coupled with the T-Scan III system (Tekscan, MA, USA) to analyze a dynamic occlusion qualitatively and quantitatively (Figure 1). However, the sensitivity and variability of high definition sensor are affected by some repeated closures over 20 times [96].

T-Scan I system was first developed in 1984 [97]. The first generation sensor (G1) is a flexible laminated epoxy matrix encapsulating a pressure-sensitive ink grid. Their software interprets the data and demonstrates in different 16 relative occlusal force levels with an approximately 0.01 sec-time increment. The data are two- or three dimensionally displayed as a snapshot or a continuous force movie. The second, third, and fourth generation sensors (G2-G4) are developed during 1992-2002. The G4 HD sensor provides a better data capture than all previous sensors. The T-Scan II system is developed later in 2006 and the T-Scan III with a turbo mode recording has been introduced since 2008. Its speed of recording is improved to a 0.003-sec time increment, causing some more precise occlusal data [96,98].

Due to several variations each time the subjects bite down, the patients' positions, and the occlusal contacts' locations, the occlusal force's absolute value is clinically unmeasurable. Hence, a measurement of the occlusion's absolute force can be misled. The T-Scan III system, which detects an unequal distribution or a relative occlusion, indicates where an excessive force is concentrated, the changes in occlusion over time of which are more clinically useful (Figure 2 and Table 9) [91].

Table 9 Principles and clinical applications of the T-Scan III system [91]

Principles and components	T-Scan III system	Clinical applications	Information
- A thin (100 micron) flexible disposable sensor inserted into an an autoclavable sensor - The sensors: : can be used repeatedly/person. : 1,370 active pressure sensing locations (1,122 pressures for small sensors). : encloses a double handle plugged into the USB port of a personal computer - A force applied to each of these cells modifies the electric conductivity of the ink. - The program records and analyzes the differentials of applied voltage. - The program gives relative values of the force and duration of occlusal contacts, with a time precision 10 milliseconds.	T-Scan system (1984) introduced the system as: - registering inter-arch occlusal contacts dynamically during various mandibular movements representing them in a graphic form in real time - giving information about their duration and relative force - facilitating the diagnosis of occlusal dysfunctions - guiding practitioners in delivering occlusal equilibrium of natural, prosthetic teeth, and implant-supported prostheses Scientific validations of the system *2nd and 3rd generations:* - sensitivity improved - no effect on the measurements from the repeated tests - quantifying and displaying relative occlusal force information, allowing clinicians to minimize repeated errors of incorrect occlusal contact selection - helping ensure the high quality and complete occlusal end-results from clinical occlusal treatment - readily identifying the very first contact point - determining the contact time-sequencing, and the percentage of relative occlusal force force between numerous occlusal contacts - better identifying many interfering contacts	New patient check up Fixed prostheses Removable prostheses Implant TMD appliances Occlusal equilibrium Orthodontics Oro-facial pain treatment	Distribution of force by percentage around the arch Timing of the force as to which forces are early or late Presence of interference to closure Balance of forces left-to-right and/or front-to-back at any point in closure Effectiveness of guidance patterns provides somatosensory muscle control Evidence of abnormal dental force secondary to injury, pain, and inflammation Presence and timing of forces being above or below average for the patient

Descriptions and details of the T-Scan III system (desktop) are as follows (Figure 2):

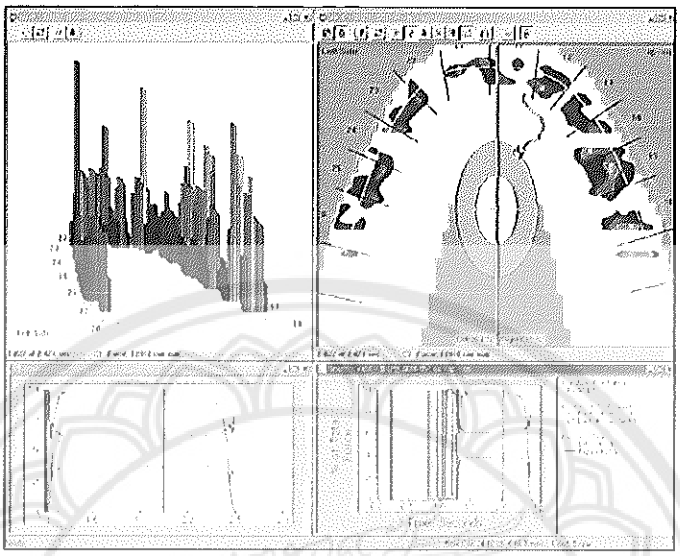


Figure 2 Four different occlusal forces and time analyses windows shown by a T-Scan III desktop

Source: Kim, J. H. [93]

Top left corner analysis window shows 3D colored bar graphs displaying the amount of relative occlusal force and the intensity of force per contact represented by the colors and each bar's height.

Top right corner analysis window shows the occlusal contact forces surrounded by a yellow outline that locates the contacts. An investigator adjusts a problematic occlusal contact by finding its location in two dimensions.

The left and right arch halves are outlined in green and red, respectively. Their respective arch half-force percentages are calculated and displayed for analyses at the bottom.

The anterior and posterior regions can also be displayed by dividing the two-dimensional window into four quadrants (pink and aqua colors added).

In Figure 3, two lower windows show the graphs of force versus time. The elapsed time and the changing percentage of occlusal forces in both sides of the arch are indicated by X- and Y-axes, respectively. Percentages of occlusal force changing across time are illustrated in both left (green line) and right (red line) arch halves. The total force (black line) of the combined left and right arch halves is described.

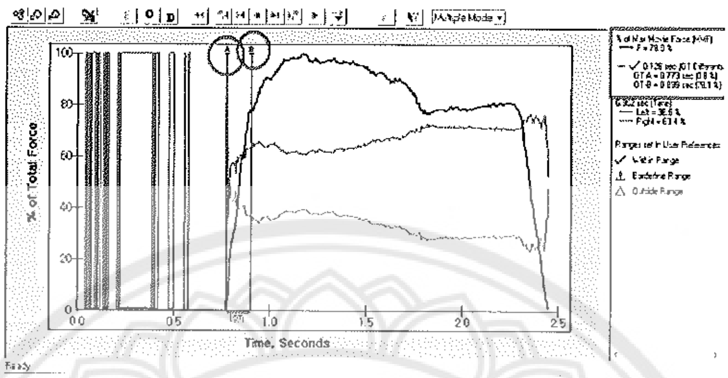


Figure 3 The time from point A to point B indicated by occlusal time (OT) in this force-versus-time graph

Source: Kim, J. H. [93]

The distributions of occlusal forces play a role in the masticatory performance. An unbalance distribution of the occlusal forces explains the masticatory muscles' certain abnormal activities [44,99-100]. By using surface EMG, some reports on significant differences of masticatory muscles' activities in each malocclusion type have been available [101-102]. Some controversial report on the lack of relationship between the symmetry of occlusal contacts and surface EMG activity has been documented in asymptomatic young adults [44].

Whether the force comes from the maxillary or mandibular teeth is indeterminable by the T-Scan, despite its capabilities of force and bite dynamic assessments. This is due to the fact that only the forces between the teeth are recoded. However, various occlusion types have been reported to possess different occlusal forces, by using the T-Scan III. Consequently, the T-Scan patterns provide some complementary information not assessable by a clinician [103].

T-Scan system has been used to quantify the data of all occlusal contacts [2,35,37,93-95,100,104-105] by registering various parameters such as bite length, the tooth contacts' timing, and their forces with a great precision. It is useful in orthodontic diagnosis and treatment plan to accomplish occlusal balances [2,39-40,76,98,104]. Moreover, it is applicable for an analysis of functional occlusion by some evaluations and comparisons of occlusal force distributions [33,40,44,100,105-106] and DT [42,47,107].

Because of its rapidity and accuracy in identifying the distribution of tooth contacts, a T-Scan system can be clinically used for some diagnostic aids [94-95]. By using a T-Scan system, a report on the occlusal force distributions in subjects with normal occlusion has shown a tendency of the distribution toward the posterior region [104].

Disclusion time (DT) as an important tool for dental treatment

Disclusion is the separations of contacting molars during three mandibular excursions (right, left, and protrusive movements).

In Figure 4, the time difference between points C and D is the DT, the duration of time required to reach solely the canine or anterior teeth after leaving from MIP during a mandibular excursion. It is the time from post-formation of anterior or canine guidance to the point with the loss of molar contact during lateral excursion (right [Rt]-DT and left [Lt]-DT) or protrusion (Pro-DT).

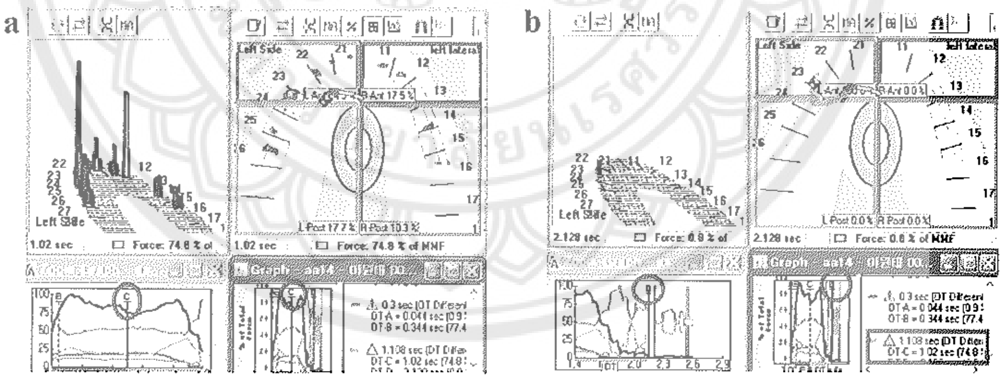


Figure 4 (a) Maximum intercuspal position, point C; and (b) mandibular left excursion, point D

Source: Kim, J. H. [93]

A DT of less than 0.41 sec is considered normal/physiologic mean [6,91,93]. It has been reported that the longer the DT, the greater the interference of molars during lateral excursion or protrusion [91], and the longer the masseter muscles' excessive firing [41]. Some occlusal factors promoting a prolonged DT are Angle's malocclusions, an anterior open bite, a presence of occluding third molars, a poor vertical orientation of opposing posterior tooth, a lack of opposing canine contacts in the MIP, a shallow anterior guidance contact, an edge-to-edge anterior tooth intercuspation, an absence of vertical overlap, an exaggerated curve of Spee, and a presence of tipped-up molar orientation [98]. When compared to the healthy, patients with TMD possess a longer DT [41,106], which coincides with their masseter and temporalis muscles' abnormal activities [41].

Patients with a chronic facial pain disorder possess an increased DT, and an occlusal adjustment improving the symptoms helps decrease their DT [6,41]. An adjustment of the DT to be less than 0.4 sec per excursion prevents an increased muscular excessive force from excessively loading the posterior teeth [41,108]. In lateral excursions, shortening the time to less than 0.4 sec for a disclusion of the posterior teeth results in some 5- to 10-fold decreases in the masseter and temporalis muscles' activities. Hence, a clinical achievement of 0.5 sec (or less) per excursion has been recommended in the DT reduction [41,108].

Some difference in occlusion balances between patients with TMJ dysfunction and those with normal TMJ function has been documented. According to the T-Scan indices, a balanced bilateral occlusion with the center of force appearing in the first molar region is observable in the latter group. On the other hand, those with the dysfunction possess an asymmetrical and imbalanced occlusion [91].

In an orthodontic treatment, a balanced distribution of occlusal forces, a good intercuspation, and a smooth lateral excursion should be established [2]. However, some different skeletal profiles probably affect the occlusion's performances by making an imbalanced distribution of the occlusal forces between each dental arch side. In addition, by using the T-Scan system in some patients with congenital muscular dystrophy and an occlusal disharmony, the time and occlusal force parameters are asymmetrical and the antero-posterior center of force is not always located in the first molar region [105].

An anterior guidance plays an important role in the masticatory system's functions [3,20,41] and influences DT. Various malocclusion types have been reported to affect the mean DT [107]. The longest DT has been found in patients with Class II malocclusion lacking anterior contacts [107,109], which predispose some extensions of their posterior teeth during excursion. Moreover, patients with anterior open bite and those with Class II division 1 malocclusion lacking anterior contacts have possessed a prolonged DT [107]. Since a proper anterior guidance can be formed by an orthodontic treatment [104] and a pre-orthodontic evaluation of the occlusal problem is important, the use of DT has been recommended for its diagnostic tool [107-108].

CHAPTER III

RESEARCH METHODOLOGY

Population and samples

All subjects who were dental students or came for some dental treatment at Dental Hospital, Naresuan University from April to June 2018 and had at least 28 fully erupted permanent teeth were included in this study.

Since the population number was unknown, the proportion of population was estimated by using the value described elsewhere [72]. An application [110] to calculate the sample size was used with the minimally estimated sample size represented by n, the estimated proportion of an attribute present in the population by p, the Z-distribution's value corresponding to the chosen alpha level by Z (equivalent to 1.96 for 0.05), and the margin of error by e. Its equation was as follows:

$$n = \frac{p(1-p)Z^2}{e^2}$$

When calculating a sample for the proportions of p = 0.57, Z = 1.96, and e = 0.1, one hundred subjects of both genders were included in this study. According to Angle's classifications (Class I, Class II division 1, Class II division 2, and Class III), they were separated into four groups (n = 25 per group).

Inclusion criteria:

Those with all of the following characteristics were included in this study.

1. Full eruptions of at least 28 permanent teeth
2. Permanent dentition with each quadrant consisting of a central incisor, a lateral incisor, a canine, a first premolar, a second premolar, a first molar, and a second molar (symmetrical dental arch form and equal number of teeth)
3. Willing to participate in and to sign the informed consent form of this study

Exclusion criteria:

Those with either of following characteristics were excluded from this study.

1. Restoration(s) with dental implant or fixed prosthesis
2. Past or on-going orthodontic treatment or TMD management

3. Molar relationship's classification on one side different from that on the other
4. TMD and/or any of parafunctional habits

Materials and methods

Materials

1. T-Scan III occlusal analysis system, Version 9.1.9 (Tekscan)
2. T-Scan sensor (Tekscan)
3. Patient screening form (Figure 5)

Post-interview and clinical examination by Dr. Jittima Pumklin (JP), a Thai Board certified specialist in the field of occlusion and orofacial pain, the patients' TMD history, sign, and symptoms, if any, were recorded in the patient screening form.

4. Clinical oral examination (Figure 6)

An intra-oral investigation into a subject's number of teeth, restoration(s), and Angle's classification were performed by the principal investigator (Miss Titirat Chutchalermpan; TC).

5. T-Scan data form (Figure 6) was constructed for the records of the data from the T-Scan III system. The form comprises the percentage of force distributions in each region. DT (sec) in each excursive movement were also included.

6. A mouth mirror, a dental explorer #5, and a pair of cotton pliers
7. A shim stock occlusion foil (Hanel, Canada)
8. Irreversible hydrocolloid impression material (Kromopan; Zhermapol, Poland)
9. Plaster of Paris (Siam Gypsum Industry, Saraburi, Thailand)
10. LCD digital vernier caliper (Mitutoyo, Mitutoyo Co, Kanagawa, Japan)

The study was approved by Naresuan University Ethical Committee, Phitsanulok, Thailand (IRB No. 0721/60). The research's objectives and prospective results, as well as the advantages and disadvantages of a subject's participation, were thoroughly explained to the subjects in order that they completely comprehended.

Subject NO: ....

Patient screening form

Subject's name: ....Age: ....Gender: ....

Tel: ....

History taking

1. Head/neck accident: ....
2. Previous orthodontic treatment (Specify, if any): ....
3. Previous TMD treatment: ....
4. Parafunctional habits:

☐ Day time bruxism ☐ Night time bruxism

☐ Unilateral chewing: ☐ Left side ☐ Right side

☐ Other (Specify): ....

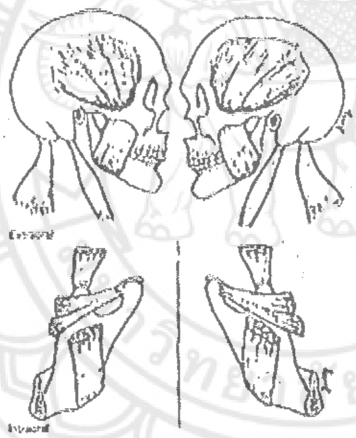
Sign and symptoms

	Pain		
	R	L	No
Maximum opening			
Left: lateral excursion			
Right: lateral excursion			
Protrusion			

TMJ symptoms

Rt	Lt	Negative
		Painful (Verbal)
		Painful on function
		Pain on palpation
		Clicking
		Popping
		Crepitus
		Ear ringing
		Hypomobility
		Chronic subluxation

Muscles palpated



☐ Approved ☐ Not approved

Signature..................................

(Dr. Jittima Pumklin)

Date: ..../....../......

Figure 5 A patient screening form used in this study

Subject NO: ....

Clinical oral examination

1. Teeth (mark X on the tooth that loss due to history of extraction or clinical missing)

8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8
8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8

2. Restoration(s) with dental implant or fixed prosthesis: ☐ No ☐ Yes

3. Angle's Classification of malocclusion:

☐ Class I ☐ Class II division 1 ☐ Class II division 2 ☐ Class III
☐ Class II subdivision ☐ Class III subdivision

4. No contact in MIP

8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8
8	7	6	5	4	3	2	1	1	2	3	4	5	6	7	8

3. Overjet = ... mm Overbite = ... mm

☐ Approved ☐ Not approved

Signature......................................

(Dr. Titirat Chutchalermpan)

Date: ..../....../......

....

T-scan data form

Relative occlusal force (in percent)	Anterior segment	Premolar segment	Molar segment
1st times			
2nd times			
3rd times			

Disclusion time (in millisecond)	Left	Right	Protrusion
1st times			
2nd times			
3rd times			

Signature..................................

(Dr. Titirat Chutchalermpan)

Date: ..../....../......

Figure 6 Two forms used in this study for clinical oral examinations and T-Scan data

Methods

The first visit

By JP, each subject's past dental history was interviewed and their problem, if any, of their occlusion, masticatory muscles, and TMJ was clinically examined for screening the problem. The data was recorded in a patient screening form (Figure 5). By TC, all subjects were intra-orally explored into their restoration(s) and classified into Angle's classification. In addition, their occlusal contacts on both sides were examined by using a shim stock occlusion foil. The data was recorded in a form (Figure 6). Impressions of the qualified subjects' maxillary and mandibular dental arches were taken (Figure 7A) by using an irreversible hydrocolloid material, followed by a construction of diagnostic maxillary and mandibular models. Mesio-distal width of each maxillary tooth (Figure 7B) was measured by using a digital vernier caliper, and the data was recorded into a T-Scan III software for the determination of each subject's dental arch dimension.

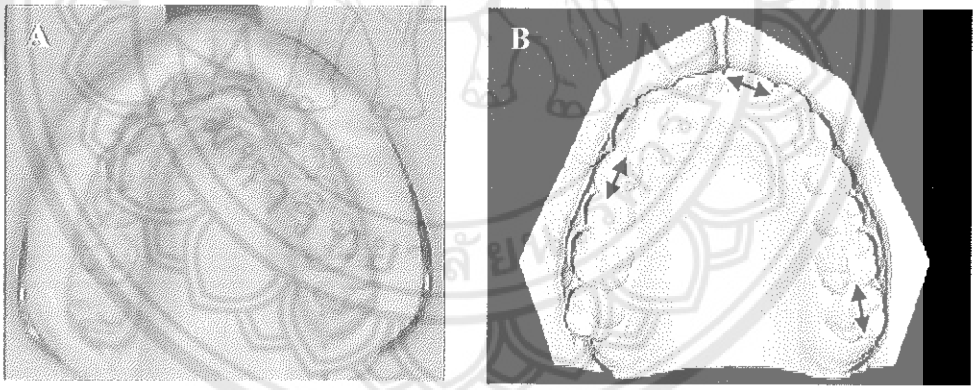


Figure 7 A preliminary impression of all teeth in the maxillary dental arch (A) and the maxillary dental model for the measurement of each tooth's width (B)

Sources: (a) http://www.infodentis.com/fixed-prosthodontics/dental-cast.php

(b) http://www.scielo.br/pdf/dpjo/v16n4/en_a22v16n4.pdf

The second visit

One week after the first visit, all selected subjects' occlusions were recorded by using a T-Scan III system. They were instructed to sit in an upright position (their Frankfort horizontal plane parallel to the floor) and practice three mandibular movements (occluding into MIP, lateral excursions, and protrusion) several times using a portable mirror as the reflecting object. An appropriate sensor was placed on the maxillary arch's occlusal surfaces. Pre-determination, the sensor's sensitivity would be adjusted by limiting only the first three pink high force columns.

To determine the occlusal force distribution, the subjects were asked to bite into MIP and hold in this position for 3-5 sec before releasing. The occlusal force distribution (in percentage) was showed on each tooth along the maxillary dental arch. The MIP mode of T-Scan software was selected to record the relative occlusal force. Summations of the relative occlusal force's percentage in each region (Figure 8) at MIP was recorded.

To determine the DT, each subject was asked to be in MIP for 3-5 sec after that moved to lateral excursions and protrusion. The graphs of force versus time and timing table showed on their DT, which was determined from points C to D (Figure 8). The end of their DT was recorded, when the canine or anterior teeth were contacted during mandibular movement. Each movement was repeated three times and their mean values were presented.

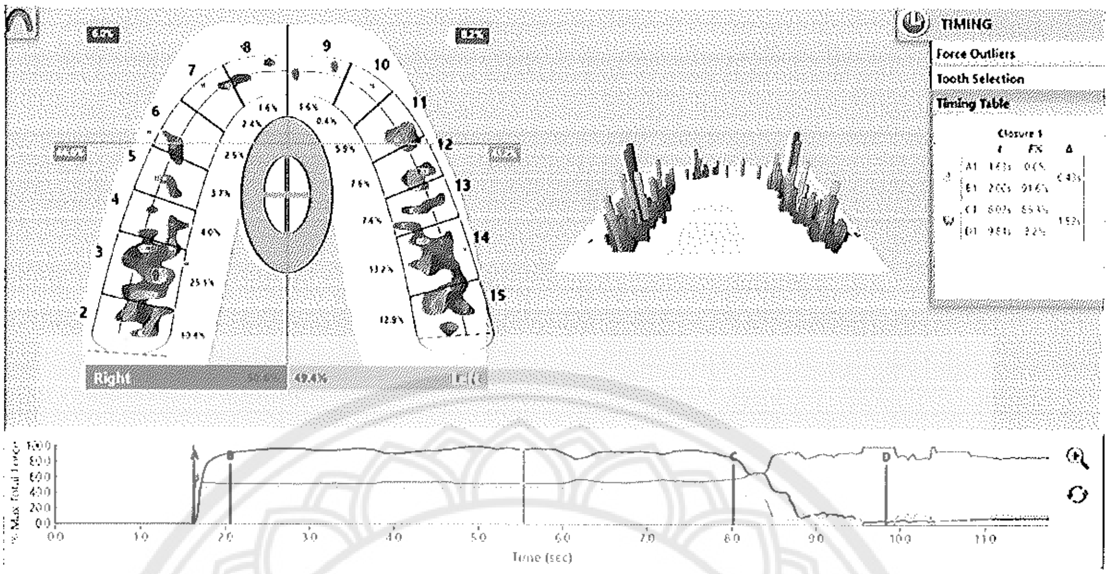


Figure 8 Occlusal force distributions (in percentage) on each tooth along the maxillary dental arch and in each region. Timing table and the graphs of force versus time are shown at the far right corner and at the bottom, respectively

Analyses of the data

The obtained data were analyzed using PASW Statistics for Windows, Version 17.0 (SPSS, IL, USA). A standard descriptive statistics was used for calculating means and standard deviations of relative occlusal force distributions in each region (anterior, premolar, and molar regions) and mean DT (right excursion, left excursion, and protrusion).

Since a normal distribution was seen in the study, the usage of a Shapiro-Wilk test was confirmed. A one-way analysis of variance, followed by a *post hoc* analysis by Least Significant Difference (LSD), was used for comparisons of the relative occlusal force distributions' mean summations in each region (anterior, premolar, and molar regions) and comparisons of the mean DT (right excursion, left excursion, and protrusion) among malocclusion types. All statistics were conducted by using a 95% confident interval.

All conductions in this study were summarized in a flow-chart (Figure 9).

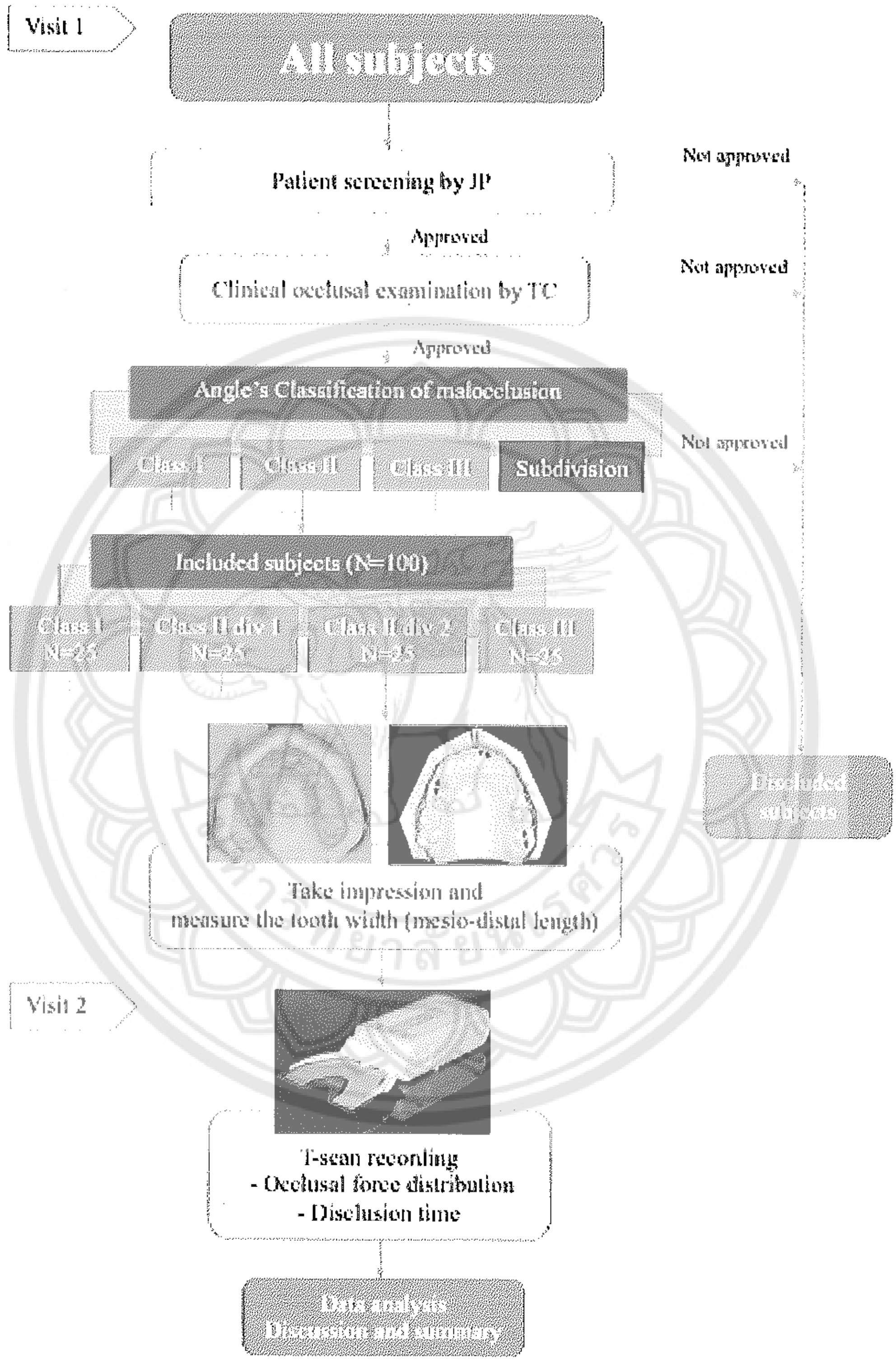


Figure 9 A flow-chart of this research methodology

CHAPTER IV

RESULTS

One hundred subjects in the study were divided into four groups (25 subjects per group) of Class I, Class II division 1, Class II division 2 and Class III malocclusions, according to Angle's Classifications.

For gender distributions, Class I contained 14 females (56%) and 11 males (44%), Class II division 1 16 females (64%) and 9 males (36%), Class II division 2 13 females (52%) and 12 males (48%), and Class III 16 females (64%) and 9 males (36%).

Means and standard deviations of the subjects' age were as follows: 21.5±0.78 years in Class I, 22.0±0.55 years in Class II division I, 23.5±1.04 years in Class II division 2, and 22.5±0.44 years in Class III. Among malocclusion types, there was no statistically significant difference (P = 0.716) in their mean age.

The highest mean overbite was noted in subjects with Class II division 2 malocclusion, while the lowest one in those with Class III malocclusion. The highest mean overjet was seen in subjects with Class II division 1 malocclusion, while the lowest one in those with Class III malocclusion. There were some statistically significant differences in the mean values of overbite (P = 0.000) and overjet (P = 0.000). However, there was no significant difference (P = 0.614) in the mean overjet of the subjects with Cass II division 2 malocclusions and those with Class III malocclusion. Distributions of gender, age, overbite, and overjet of the subjects in each malocclusion type were shown in Table 10.

Table 10 Characteristics of subjects according to gender, age, overbite, and overbite

Malocclusion type	Gender			Age (years)			Overbite (mm)			Overjet (mm)		
	Female (%)	Male (%)	Total (N)	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Class I	14 (56%)	11 (44%)	25	21.5 ^{a}	0.78	18.0-25.0	2.42 ^{a}	1.05	0.50-5.00	2.52 ^{a}	1.04	0.50-4.00
Class II division 1	16 (64%)	9 (36%)	25	22.0 ^{a}	0.55	18.0-26.0	3.10 ^{b}	1.11	1.00-5.50	4.24 ^{b}	1.50	2.00-9.00
Class II division 2	13 (52%)	12 (48%)	25	23.5 ^{a}	1.04	18.0-31.0	4.70 ^{c}	1.42	2.50-8.00	1.62 ^{c}	0.67	0.50-3.50
Class III	16 (64%)	9 (36%)	25	22.5 ^{a}	0.44	18.0-27.0	1.44 ^{d}	0.95	0.00-3.50	1.46 ^{c}	1.11	(-1.00)-4.00
Total	59 (59%)	41 (41%)	100 (100%)									
P				> 0.05			< 0.05			< 0.05		

In each variable, the same uppercase letters indicate non-significant differences ($P > 0.05$).

Occlusal force distributions (in percentage) among malocclusion types

Relative occlusal force distributions on each tooth of the dental arch were demonstrated in Figure 10. Summation of the force distributions was divided into three regions, that is, anterior, premolar, and molar. Mean values of force distributions in such regions were shown in Table 11.

In each region, there was no significant difference in the mean force distribution among malocclusion types (*P* = 0.220, 0.316, 0.627, respectively). In the anterior region, the subjects with Class II division 2 showed the highest mean force distribution, followed by those with Class III, Class II division 1, and Class I malocclusions, respectively. In the premolar region, the subjects with Class III showed the highest mean force distribution, followed by those with Class II division 1, Class I, and Class II division 2 malocclusions, respectively. In the molar region, the subjects with Class I showed the highest mean force distribution, followed by those with Class II division 1, Class II division 2, and Class III malocclusions, respectively.

In each malocclusion type, there was some significant differences (*P* = 0.000) in the mean force distributions among the regions. Similar patterns of force distributions were observed in each malocclusion type, with the most force distributions towards the molar region. The highest value was detected in the molar region (61.65-66.42 %), while the lowest one in the anterior region (8.93-13.07%). The mean force distributions in each malocclusion type were shown in Table 11 and Figure 1.

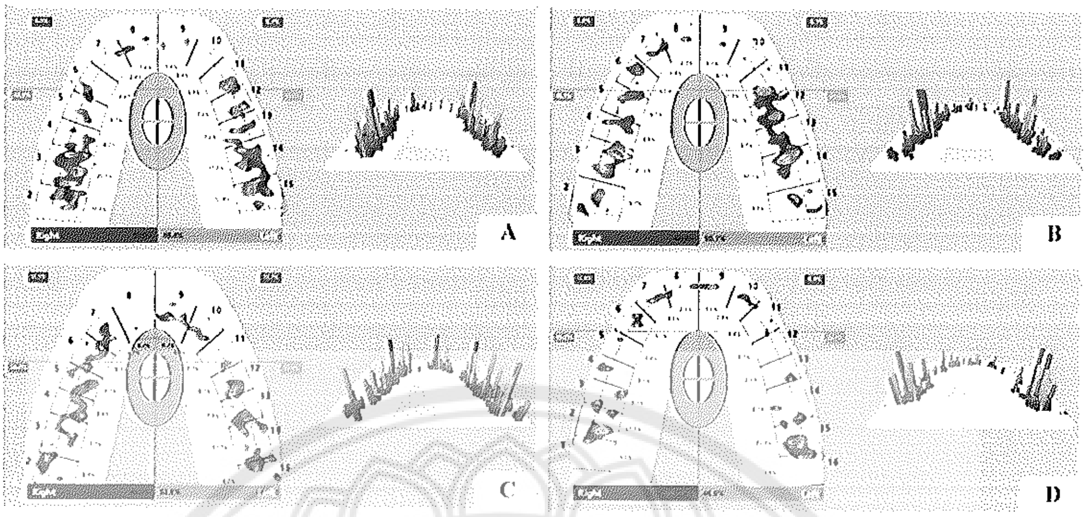


Figure 10 The relative occlusal force distributions recorded on each tooth of the dental arch in Angle's Class I (A), Class II division 1 (B), Class II division 2 (C), and Class III (D) malocclusions in two- (left side of each malocclusion) and three- (right side of each malocclusion) dimensional images by using a T-Scan III system. The Universal Numbering System is shown on each maxillary tooth's buccal side.

Table 11 Subjects' force distributions in each tooth region

Malocclusion type	Force distributions (%)												
	Anterior region				Premolar region				Molar region				
	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	P
Class I	8.93 [a,a]	6.31	0.30	19.40	24.74 [a,b]	9.42	12.90	46.70	66.42 [a,c]	12.63	39.20	86.87	< 0.05
Class II division 1	9.44 [a,a]	6.75	0.00	26.83	24.93 [a,b]	7.25	13.70	38.77	65.80 [a,c]	11.66	42.37	83.03	< 0.05
Class II division 2	13.07 [a,a]	8.35	1.17	26.13	22.93 [a,b]	9.92	8.10	47.97	63.87 [a,c]	16.20	25.93	87.87	< 0.05
Class III	10.58 [a,a]	8.46	0.00	30.87	27.78 [a,b]	11.51	13.00	49.53	61.65 [a,c]	15.33	37.57	87.00	< 0.05
P	> 0.05				> 0.05				> 0.05				

In each variable, the same uppercase letters indicate non-significant differences ($P > 0.05$).

For force distributions, the first uppercase letters indicate comparisons in the same column, while the second ones the same row.

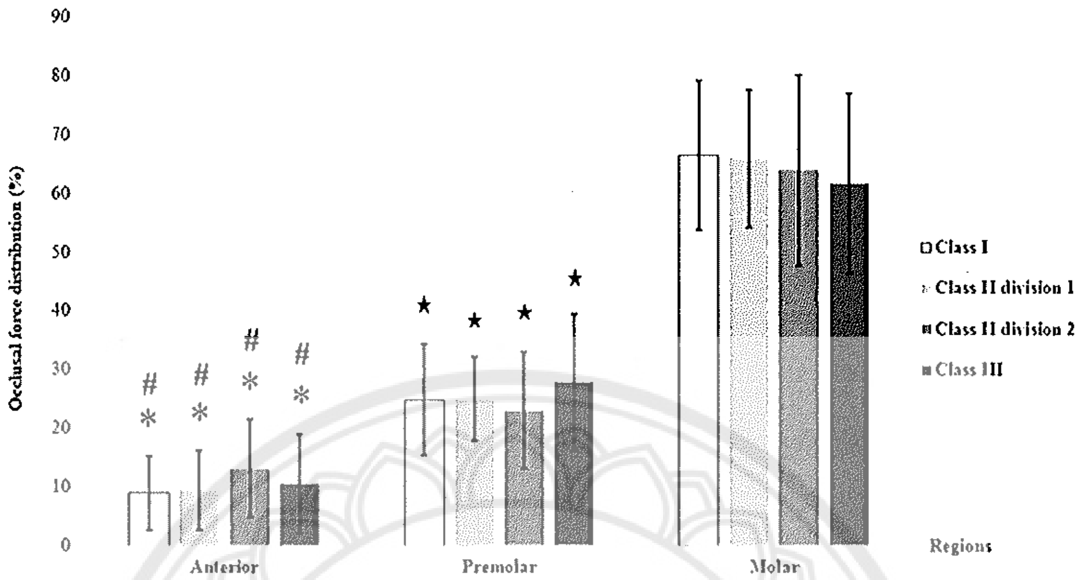


Figure 11 Mean force distributions in each region among the malocclusion types. Some inter-group statistically significant differences (*P* < 0.05) in each malocclusion's mean force distribution are marked with asterisks (*), hashes (#), and stars (★). *, comparisons between anterior and premolar regions; #, comparisons between anterior and molar regions, and ★, comparisons between premolar and molar regions

DT among malocclusion types

The subjects' DT (sec) were recorded in each excursion (left excursion, right excursion, and protrusion) and shown on the timing table (ΔC-D) in Figure 12.

Mean DT of subjects with four different malocclusions were shown in each excursion (Table 12). The subjects with Class III malocclusion had the longest mean DT in all excursions (3.19±1.35 sec, left excursion; 3.28±1.25 sec, right excursion; and 3.01±1.54 sec, protrusion). The shortest ones (2.08±0.66 sec, left excursion; 2.15±0.94 sec, right excursion; and 1.88±0.99 sec, protrusion) were detected in those with Class I malocclusion. Some significant differences in the mean DT were found among malocclusion types ($P = 0.000$, left excursion; $P = 0.003$, right excursion; and $P = 0.002$, protrusion). By using a *post hoc* test by LSD, some significant differences in the mean DT were revealed in those with Class III malocclusion, when compared to those with other types (Figure 13).

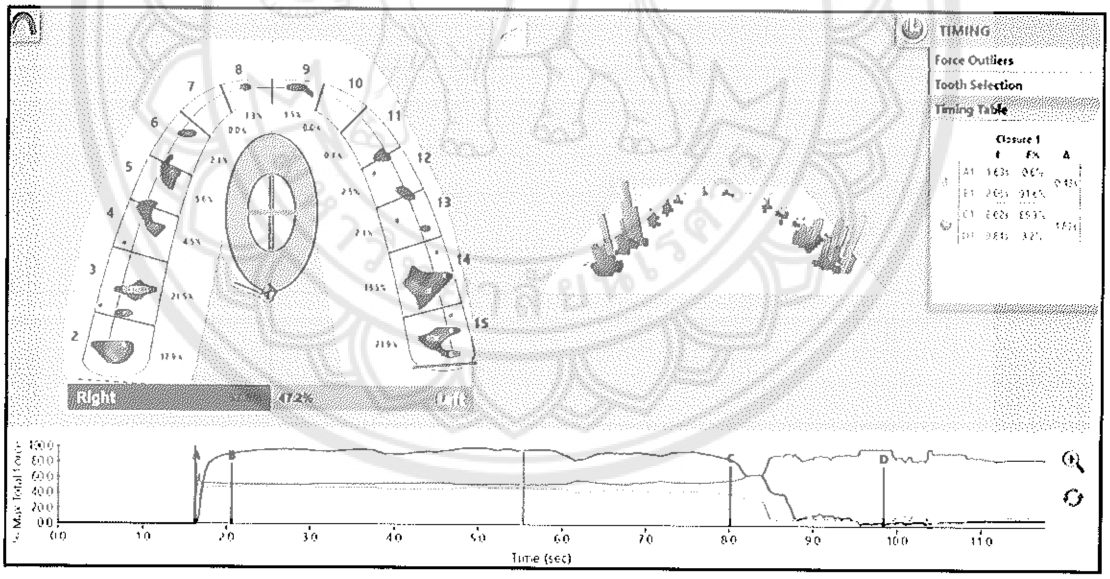


Figure 12 Timing table with the recorded disclusion time (ΔC-D) in two- (left-sided horseshoe shape) and three- (right-sided horseshoe shape) dimensional images by using a T-Scan III system. The Universal Numbering System is shown on each maxillary tooth's buccal side.

Table 12 Subjects' disclusion time in each excursion among malocclusion types

Malocclusion type	Disclusion time (sec)														
	Left excursion					Right excursion					Protrusion				
	Mean		SD	Min	Max	Mean		SD	Min	Max	Mean		SD	Min	Max
Class I	2.08	a	0.65	0.50	3.21	2.15	a	0.94	0.35	3.68	1.88	a	0.99	0.35	4.04
Class II division 1	2.13	a	0.74	0.67	3.65	2.58	a	1.16	0.90	5.71	2.08	a	1.11	0.47	5.00
Class II division 2	2.12	a	0.72	1.02	3.52	2.37	a	1.07	0.56	4.11	2.07	a	0.68	1.17	3.48
Class III	3.19	b	1.34	0.62	5.63	3.28	b	1.25	0.67	5.25	3.01	b	1.53	1.01	6.29
P	<0.05					<0.05					<0.05				

Different uppercase letters indicate intra-column statistical differences ($P < 0.05$).

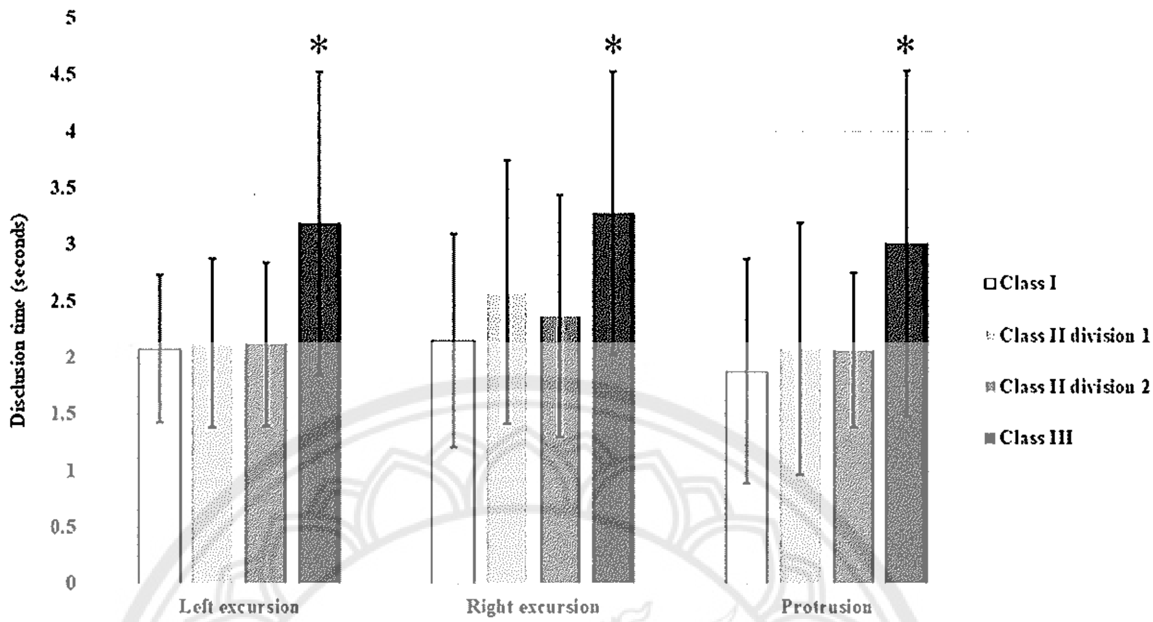


Figure 13 Mean values of disclusion time in each excursion among malocclusion types. Asterisks (*) indicate some statistically differences in the mean disclusion time in each excursion of subjects with Class III malocclusion, when compared to those with other malocclusion types.

CHAPTER V

DISCUSSION

Being the first clinical study by using a T-Scan III system, this study aimed at comparing the percentage of force distribution in each region and DT of each excursion among various malocclusion types. Our results clearly revealed some similar force distributions and some significant DT difference among malocclusions.

The sample size in the study was adequate for calculations by an equation. It comprised a total of one hundred subjects, with an age between 18 and 31 years old. Regarding their gender and mean age, no statistically significant difference was found among malocclusions. According to Angle's classifications, they were divided into four groups, that is, Class I, Class II division 1, Class II division 2, and Class III malocclusions (25 subjects per group).

Some masticatory performances have been reported to affected by anatomical and physiological characteristics, for example, age, gender, dental health status, periodontal support, craniofacial morphology, and TMD signs and symptoms [92,111]. Subjects with full eruptions of at least 28 permanent teeth was thus an inclusion criterion of this study. Occlusal forces and contacts are changed in subjects with dental implant, dental prosthesis. Due to post-orthodontic treatment, their previous dental positions are modified to obtain new ones [35,111]. Intra- and inter-arch relationships are changed to new occlusion status, the dental patterns and occlusal contacts of which lead to some differences in the forces distributions and contact timing [35,112]. DT values in post-orthodontic patients become longer, when compared to those in non-orthodontic patients with normal occlusion [41-42]. Among a group of subjects with TMD, some occlusal stabilities are significantly associated [100,113]. In addition to TMD, the subjects possess a higher frequency of premature contacts, a greater bilateral asymmetry of occlusal forces, and a prolonged DT [100]. A centric slide with a distance over 2.0 mm and balancing interferences are related to TMD etiology. Occlusal contacts with their opposing teeth are also defined by dental alignment and arch shapes [76,114]. The above factors, if any, among our subjects possibly caused some differences in force distributions and DT. For fear of such undesirable effects on the results, subjects with either dental implant, dental prosthesis, past or undergoing orthodontic treatment, or TMD were excluded.

The present data included the subjects' various dental malocclusions classified by Angle, but not their skeletal pattern. Thus, only some effects of different dental malocclusions on occlusal force distributions and DT were revealed. By using a Dental Prescale® system unaffected by antero-posterior skeletal patterns or molar relationships, the measurable occlusal forces are significantly lower in subjects with malocclusions, when compared to those with normal occlusion [75]. Despite an indication of a comparatively low occlusal force in a hyperdivergent facial pattern, when compared to that in a hypodivergent one, some differences in the skeletal patterns are not the primary cause. On other hand, they are considered the secondary result induced by some differences in the occlusal contact areas, according to the facial patterns [75]. Bite force at the molar region are twice as great in the normal as in the long-faced subjects, and short-faced subjects are able to generate some higher forces than those with normal face [75]. Such data indicate an irrelevance of the skeletal pattern and molar classifications to the occlusal forces and go along well with ours. In spite of some differences in the devices used in their research (Dental Prescale® system) and ours (T-Scan III system), the reasons of such consistencies needed some explanations. Because of its objectives of comparing the occlusal force distribution and DT among different malocclusion, an absence of subjects' skeletal pattern classifications led to a limitation of this study. For further study, some investigations among subjects with different skeletal patterns are thus recommended.

An establishment of a normal occlusion is an orthodontic treatment objective [49,115]. In a good occlusion, both static and dynamic factors should be assessed. Being possible effects on the masticatory performances, the factors include good force distributions, proper DT, and a mutually protected occlusion. Clinically, an occlusal force is indirectly assessed by the locations of occlusal contacts using non-digital occlusal indicators (an articulating paper, an occlusal indicator wax, a silicone impression, or a shim stock foil) [116-118]. Such widely used indicators are unable to measure either an amount of occlusal force or a sequence of contacts [114]. Their thickness, strength, and other physical properties result in low sensitivity and reliability [119]. Because of the mentioned limitations of the non-digital ones, some digital occlusal indicators have been developed—gnathodynamometer [81], a Dental Prescale system [75], and a T-Scan system [23], respectively.

The firstly developed T-Scan I digital occlusal indicator has been substituted by the T-Scan III system, the newest version with an improvement of its property and a greater precision [39,114,119]. With several advantages in dentistry, the T-Scan III is used to evaluate and provide measurable forces and timing discrepancies indicating the need for an occlusal correction. The occlusal discrepancies are precisely adjustable to optimize both forces and timing [120]. In orthodontics, the T-Scan III is used to obtain a stable occlusion during the orthodontic finishing stages [121]. The T-Scan III can record and display the sequences of occlusal contacts, percentage of forces on each tooth, and percentage of forces on each side of a dental arch and on each region (anterior, premolar, and molar ones). Its high definition sensor is a pressure-sensitive foil. Due to the 100-micron thickness, the subjects must be trained to accurately perform both closure and excursions. For a more precise value, each movement needs repetitions. From these situations, each subject must bite a recording sensor several times. The high definition sensor is improved to repeat measurements over 20 times, which does not affect the variability [96]. With its high reliability [39,92,97], our subjects were instructed to bite into MIP and excursions repeatedly three times. Owing to the U-shaped HD sensor's two sizes (small and large) and different dental arch form among the subjects, some error interpretations and wrong data might be obtained. Impressions of each subject's dental arches were thus taken, followed by constructions of the diagnostic models, measurements of the tooth-sizes, and saving into the tooth chart of the T-Scan software before recoding. The processes caused the dental arch to be customized into a graphic image and matched with the sensor's recording. Some reductions of the data's error, if any, might be obtained to offset all subjects' misunderstandings of one investigator's training and instructions on occluding the teeth into the recording sensor.

Regarding the occlusal force distributions (in percentage) among malocclusions, the posterior region had a higher occlusal force than the anterior in each malocclusion type. They were 61-67% and 8-11% in the posterior and anterior regions, respectively, and coincided well with those in some studies [103,120]. Subjects with normal occlusion show a similar pattern of the occlusal force distributions along the dental arch from first premolar to second molar [40,94,104-105]. From all malocclusions in this study, a wide range of forces in each region was observable. In the anterior region, subjects with Class II division 2 revealed the highest occlusal force, when compared to those with other malocclusion types. In addition, it was seen among our subjects that the larger the overbite, the higher the occlusal forces. However, such observable results disagreed with an absence of the correlation between the overbite and Angle's classifications in a report [103].

The highest bite forces and the most occlusal contact areas are recognized in normal occlusion, followed by Class I, Class II division 1, Class II division 2, and Class III malocclusions, respectively [68,72,76,122-123]. By using a T-scan in subjects with normal occlusion and those with malocclusions, the same patterns of occlusal forces are detectable [40,103,120]. Due to the absence of force distribution comparisons among malocclusions and the lack of dental arch separations into regions, their unclear conclusion remains. In the present study, no significant difference in the force distribution was observed among malocclusions, implying an absence of the correlation between malocclusions and some masticatory performance in a static occlusion. However, some studies have shown less masticatory performances in malocclusions, when compared to that in normal occlusion [100,124]. Our inspections of the force distributions in only the antero-posterior molar relationship might contribute to the discrepancy. Hence, examinations of the vertical and transversal forces, together with classifications of the subjects' skeletal patterns, are necessary for some other comprehensible conclusions.

Reports on the relationships between TMD and malocclusions are available, but with some unclear conclusions [33,125-127]. With the usage of a T-Scan system, DT is interesting for the studies of muscular activities [6,41,96]. The occlusal stability is significantly associated with TMD in young adults and TMD-patients possess a prolonged DT [100,113]. With the usage of T-Scan combined with some non-digital methods, DT in healthy group are disclosed to be less than those in TMD-subjects with balancing interferences and over-2.0-mm centric slides [113]. Some prolonged DT are also visible in TMD-patients with masticatory muscles' hyperactivity [41,100]. DT over 0.5 sec have been documented to result in some increased contractions of temporalis and masseter muscles [6,96]. On the contrary, a shortened DT (less than 0.4 or 0.5 sec) causes some reductions in both TMD symptoms and muscular hyperactivity [2,128-129], and an immediate complete anterior guidance development, a treatment method by shortening the DT, affects masticatory muscles' functions [2,128-129]. Although some DT longer than 0.5 sec were seen among all non-TMD subjects in this study, it might be explicable by a physiologic tolerance phenomenon of their adaptive capacities [128].

During excursions, the anterior guidance should be achieved for an immediate disclusion of the posterior teeth [39,50,130]. Such guidance is established by overjet and overbite, because of their importance for incisors to contact with their opposing teeth during jaw movement [39,50,130]. A report has shown that subjects with Class II possess the longest DT, followed by those with Class III and Class I malocclusions [103]. However, in all excursions examined among our subjects, the longest DT was observed in Class III, followed by Class II division 1, Class II division 2, and Class I malocclusions. The discrepancies might be explained by the usages of T-Scan's different versions and the sample size in their work and ours.

Overbite among all malocclusions, but not DT of all excursions among all malocclusions (except for those between Class III malocclusion), were significantly different. Overjet among all malocclusions (except for that between Class II division 2 and Class III malocclusions) and DT of all excursions among all malocclusions were not significantly different. They illustrated that the DT were unaffected by overbite or overjet. A relationship between overjet and prolonged DT is reported in subjects with an overjet over 3.0 mm [50]. It has been in contrast with this study's findings of a significantly shorter DT in Class II division 1 with an overjet over 4.0 mm, when compared to that in Class III malocclusion. Since negative overjet or overbite possibly affected the DT, subjects with either of them were excluded from this study. Our Class III subjects with a positive overjet and overbite showed the longest DT in all excursions, implying that the anterior guidance was not the only DT-affecting factor. Because of the fact that determinations of mandibular movement are consisted of anterior and posterior controlling factors [32], it is clearly disclosed that an individual jaw movement is controlled by some other factors, for example, condylar guidance, plane of occlusion, cusp height, and curve of Spee.

Some relationships between skeletal malocclusions and TMD have been documented [131-133]. Hyperdivergent facial profiles, lingually inclined maxillary anterior teeth, and severely inclined occlusal planes are seen in TMD-subjects [132]. Hence, both dental and skeletal factors are related to TMD signs and symptoms. However, there is no clear conclusion between the occlusal factor- or prolonged DT-associated TMD. For the dental factors, DT in Class III malocclusion were shown to significantly differ from that in other malocclusion types of this study. Nevertheless, no relationship between overbite and DT or between overjet and DT was found in our non-TMD subjects. Since the DT results of this study were derived from Angle's classifications, some other DT researches among TMD-subjects and among subjects with different skeletal patterns are recommended.

CHAPTER VI

CONCLUSIONS

In all malocclusions, the posterior region was the area with most force distributions. In each malocclusion type, there were significant differences in the force distributions among molar, premolar, and anterior regions. Relative occlusal force distributions in each region were not significantly different among the malocclusions.

When compared to Class I and Class II malocclusions, Class III possessed the significantly highest mean DT of each excursion and the significantly longest DT in all excursions. Different excursions caused no intra-group significant difference in their mean DT.

REFERENCES

REFERENCES

1. Dawson PE. Functional occlusion: from TMJ to smile design. 4th ed. St. Louis (MO): Mosby; 2006.
2. Thumati P. Digital analysis of occlusion using T-Scan III in orthodontics. J Indian Orthod Soc. 2016;50(3):196-201.
3. Proffit WR, Fields HW, Sarver DM. Contemporary orthodontics. 5th ed. St. Louis (MO): Mosby; 2014.
4. Selaimen CM, Jeronymo JC, Brilhante DP, Lima EM, Grossi PK, Grossi ML. Occlusal risk factors for temporomandibular disorders. Angle Orthod. 2007;77(3):471-7.
5. Fujita Y, Motegi E, Nomura M, Kawamura S, Yamaguchi D, Yamaguchi H. Oral habits of temporomandibular disorder patients with malocclusion. Bull Tokyo Dent Coll. 2003;44(4):201-7.
6. Kerstein RB, Wright NR. Electromyographic and computer analyses of patients suffering from chronic myofascial pain-dysfunction syndrome: before and after treatment with immediate complete anterior guidance development. J Prosthet Dent. 1991;66(5):677-86.
7. Okeson JP. Management of temporomandibular disorders and occlusion. 4th ed. St. Louis (MO): Mosby; 1998.
8. Glaros AG, Burton E. Parafunctional clenching, pain, and effort in temporomandibular disorders. J Behav Med. 2004;27(1):91-100.
9. Gremillion HA. The relationship between occlusion and TMD: an evidence-based discussion. J Evid Based Dent Pract. 2006;6(1):43-7.
10. Trovato F, Orlando B, Bosco M. Occlusal features and masticatory muscles activity. A review of electromyographic studies. Stomatologija. 2009;11(1):26-31.
11. Baba K, Ai M, Mizutani H, Enosawa S. Influence of experimental occlusal discrepancy on masticatory muscle activity during clenching. J Oral Rehabil. 1996;23(1):55-60.
12. Ferrario V, Sforza C, Colombo A, Ciusa V. An electromyographic investigation of masticatory muscles symmetry in normo-occlusion subjects. J Oral Rehabil. 2000;27(1):33-40.

13. Ramfjord SP. The role of occlusion in temporomandibular joint and associated muscle disorders. J Gnathol. 1990;9(1):23-31.

14. Ramfjord SP. Bruxism, a clinical and electromyographic study. J Am Dent Assoc. 1961;62:21-44.

15. Thilander B, Rubio G, Pena L, de Mayorga C. Prevalence of temporomandibular dysfunction and its association with malocclusion in children and adolescents: an epidemiologic study related to specified stages of dental development. Angle Orthod. 2002;72(2):146-54.

16. Bakke M. Mandibular elevator muscles: physiology, action, and effect of dental occlusion. Scand J Dent Res. 1993;101(5):314-31.

17. Costa MD, Junior F, da Rocha Torres G, Santos CN. Evaluation of occlusal factors in patients with temporomandibular joint disorder. Dental Press J Orthod. 2012;17(6):61-8.

18. Learreta JA, Beas J, Bono AE, Durst A. Muscular activity disorders in relation to intentional occlusal interferences. Cranio. 2007;25(3):193-9.

19. Becker IM. Comprehensive occlusal concepts in clinical practice. 1st ed. Hudson County (NJ): Wiley-Blackwell; 2011.

20. Felício CM, Melchior Mde O, Silva MA, Celeghini RM. Masticatory performance in adults related to temporomandibular disorder and dental occlusion. Pro Fono. 2007;19(2):151-8.

21. Kirveskari P, Alanen P, Jamsa T. Association between craniomandibular disorders and occlusal interferences in children. J Prosthet Dent. 1992;67(5):692-6.

22. Egermark-Eriksson I, Ingervall B, Carlsson GE. (1983). The dependence of mandibular dysfunction in children on functional and morphologic malocclusion. Am J Orthod. 1983;83(3):187-94.

23. Landi N, Manfredini D, Tognini F, Romagnoli M, Bosco M. Quantification of the relative risk of multiple occlusal variables for muscle disorders of the stomatognathic system. J Prosthet Dent. 2004;92(2):190-5.

24. Henrikson T, Ekberg EC, Nilner M. Symptoms and signs of temporomandibular disorders in girls with normal occlusion and Class II malocclusion. Acta odontol Scand. 1997;55(4):229-35.

25. Seligman DA, Pullinger AG. Association of occlusal variables among refined TM patient diagnostic groups. J Craniomandib Disord. 1989;3(4):227-36.

26. Seligman DA, Pullinger AG, Solberg WK. The prevalence of dental attrition and its association with factors of age, gender, occlusion, and TMJ symptomatology. J Dent Res. 1988;67(10):1323-33.

27. Gazit E, Lieberman M, Eini R, Hirsch N, Serfaty V, Fuchs C, et al. Prevalence of mandibular dysfunction in 10-18 year old Israeli schoolchildren. J Oral Rehabil. 1984;11(4):307-17.

28. Pullinger AG, Seligman DA, Gornbein JA. A multiple logistic regression analysis of the risk and relative odds of temporomandibular disorders as a function of common occlusal features. J Dent Res. 1993;72(6): 968-79.

29. Tuerlings V, Limme M. The prevalence of temporomandibular joint dysfunction in the mixed dentition. Eur J Orthod. 2004;26(3):311-20.

30. McNamara JA Jr, Seligman DA, Okeson JP. Occlusion, orthodontic treatment, and temporomandibular disorders: a review. J Orofac Pain. 1995;9(1):73-90.

31. Wright EF, North SL. Management and treatment of temporomandibular disorders: a clinical perspective. J Man Manip Ther. 2009;17(4):247-54.

32. Okeson JP. Management of temporomandibular disorders and occlusion. 7th ed. St. Louis (MO): Mosby; 2014.

33. Luther F. TMD and occlusion part II. Damned if we don't? Functional occlusal problems: TMD epidemiology in a wider context. Br Dent J. 2007;202(1):38-9.

34. Winocur E, Emodi-Perlman A. (2012). Occlusion, orthodontic treatment and temporomandibular disorders: myths and scientific evidence. In: Bourzgui F, editor. Rijeka (Croatia): InTech; 2012. p. 327-40.

35. Cohen-Lévy J, Cohen N. Computerized occlusal analysis in Dentofacial orthopedics: indications and clinical use the T-scan III system. J Dentofacial Anom Orthod. 2012;15(2):203-28.

36. Şoaita C, Popşor S. Computer analysis of functional parameters and dental occlusion. Scientific Bulletin of the Petru Maior University of TîrguMureş. 2011;8(2):155-8.

37. Gonzalez Sequeros O, Garrido García VC, García Cartagena A. Study of occlusal contact variability within individuals in a position of maximum intercuspation using the T-SCAN system. J Oral Rehabil. 1997;24(4):287-90.

38. Wang XR, Zhang Y, Xing N, Xu YF, Wang MQ. Stable tooth contacts in intercuspal occlusion makes for utilities of the jaw elevators during maximal voluntary clenching. J Oral Rehabil. 2013;40(5):319-28.

39. Trpevska V, Kovacevska G, Benedeti A, Jordanov B. T-Scan III system diagnostic tool for digital occlusal analysis in orthodontics - a modern approach. Pril. 2014;35(2):155-60.

40. Ma FF, Hu XL, Li JH, Lin Y. Normal occlusion study: using T-Scan III occlusal analysis system. Zhonghua Kou Qiang Yi Xue Za Zhi. 2013;48(6):363-7.

41. Kerstein RB, Radke J. Masseter and temporalis excursive hyperactivity decreased by measured anterior guidance development. Cranio. 2012;30(4):243-54.

42. An W, Wang B, Bai Y. Occlusal contacts during protrusion and lateral movements after orthodontic treatment. Hua Xi Kou Qiang Yi Xue Za Zhi. 2011;29(6):614-7.

43. He SZ, Li S, Gao XH, An WW. A preliminary study on the occlusal contact changes during retention in adolescent patients. Zhonghua Kou Qiang Yi Xue Za Zhi. 2010;45(9):556-9.

44. Wieczorek A, Loster J, Loster BW. Relationship between occlusal force distribution and the activity of masseter and anterior temporalis muscles in asymptomatic young adults. Biomed Res Int. 2013;10(5):101-8.

45. Cobourne MT, DiBiase AT. Handbook of orthodontics. 2nd ed. Philadelphia (PA): W.B. Saunders; 2015.

46. Kandasamy S, Greene CS, Rinchuse DJ, Stockstill JW. TMD and orthodontics: a clinical guide for the orthodontist. 1st ed. Philadelphia (PA): Springer; 2015.

47. Singh G. Textbook of orthodontics. 2nd ed. New Delhi (India): Jaypee Brothers Medical Publishers; 2008.

48. Ferro KJ. The glossary of prosthodontic terms: ninth edition. J Prosthet Dent. 2017;117(5):C1, e1–e105.

49. Andrews LF. The six keys to normal occlusion. Am J Orthod. 1972;62(3):296-309.

50. Oltramari PV, Conti AC, Navarro Rde L, Almeida MR, Almeida-Pedrin RR, Ferreira FP. Importance of occlusion aspects in the completion of orthodontic treatment. Braz Dent J. 2007;18(1):78-82.

51. Soboleva U, Laurina L, Slaidina A. The masticatory system-an overview. Stomatologija. 2005;7(3):77-80.

52. Türker KS, Jenkins M. Reflex responses induced by tooth unloading. J Neurophysiol. 2000;84(2):1088-92.

53. Kirimoto H, Seki Y, Soma K. Differential roles of periodontal mechanoreceptors of working-side posterior teeth in triggering nonworking-side temporalis activities. J Med Dent Sci. 2003;50(1):47-52.

54. Pileicikiene G, Surna A. The human masticatory system from a biomechanical perspective: a review. Stomatologija. 2004;6(3):81-4.

55. Bakke M. Mandibular elevator muscles: physiology, action, and effect of dental occlusion. Scand J Dent Res. 1993;101(5):314-31.

56. Miyawaki S, Tanimoto Y, Kawakami T, Sugimura M, Takano-Yamamoto T. Motion of the human mandibular condyle during mastication. J Dent Res. 2001;80(2):437-42.

57. Reinhardt R, Tremel T, Wehrbein H, Reinhardt W. The unilateral chewing phenomenon, occlusion, and TMD. Cranio. 2006;24(3):166-70.

58. Egermark-Eriksson I, Carlsson GE, Magnusson T. A long-term epidemiologic study of the relationship between occlusal factors and mandibular dysfunction in children and adolescents. J Dent Res. 1987;66(1):67-71.

59. Petrović D, Vujkov S, Petronijević B, Šarčev I, Stojanac I. Examination of the bioelectrical activity of the masticatory muscles during Angle's Class II division 2 therapy with an activator. Vojnosanit Pregl. 2014;71(12):1116-22.

60. Kayukawa H. Malocclusion and masticatory muscle activity: a comparison of four types of malocclusion. J Clin Pediatr Dent. 1992;16(3):162-77.

61. Antonini G, Colantonio L, Macretti N, Lenzi GL. Electromyographic findings in Class II division 2 and Class III malocclusions. Electromyogr Clin Neurophysiol. 1990;30(1):27-30.

62. Gunturu S, Tauro SR. Electromyographic activity of masticatory muscles in different skeletal profiles. Int J Mod Trends Sci Technol. 2013;8(3):187-94.

63. Miralles R, Hevia R, Contreras L, Carvajal R, Bull R, Manns A. Patterns of electromyographic activity in subjects with different skeletal facial types. Angle Orthod. 1991;61(4):277-84.

64. Pancherz H. Activity of the temporal and masseter muscles in class II, division 1 malocclusions. An electromyographic investigation. Am J Orthod. 1980;77(6):679-88.

65. Learreta JA, Beas J, Bono AE, Durst A. Muscular activity disorders in relation to intentional occlusal interferences. Cranio. 2007;25(3):193-9.

66. Soboļeva U, Lauriņa L, Slaidiņa A. The masticatory system-an overview. Stomatologija. 2005;7(3):77-80.

67. Song JH, Cho ES, Kim ST, Ahn HJ. Change of distribution and timing of bite force after botulinum toxin type A injection evaluated by a computerized occlusion analysis system. Yonsei Med J. 2014;55(4):1123-9.

68. Araújo SCCSD, Vieira MM, Gasparotto CA, Bommarito S. Bite force analysis in different types of angle malocclusions. Rev CEFAC. 2014;16(5):1567-78.

69. Abu Alhaija ES, Al Zo'ubi IA, Al Rousan ME, Hammad MM. Maximum occlusal bite forces in Jordanian individuals with different dentofacial vertical skeletal patterns. Eur J Orthod. 2010;32(1):71-7.

70. Koc D, Dogan A, Bek B. Bite force and influential factors on bite force measurements: a literature review. Eur J Dent. 2010;4(2):223-32.

71. Farella M, Bakke M, Michelotti A, Rapuano A, Martina R. Masseter thickness, endurance and exercise-induced pain in subjects with different vertical craniofacial morphology. Eur J Oral Sci. 2003;111(3):183-8.

72. Lee H, Kim M, Chun YS. Comparison of occlusal contact areas of class I and class II molar relationships at finishing using three-dimensional digital models. Korean J Orthod. 2015;45(3):113-20.

73. Ferrario VF, Sforza C, Zanotti G, Tartaglia GM. Maximal bite forces in healthy young adults as predicted by surface electromyography. J Dent. 2004;32(6):451-7.

74. Gibbs CH, Mahan PE, Lundeen HC, Brehnan K, Walsh EK, Holbrook WB. Occlusal forces during chewing and swallowing as measured by sound transmission. J Prosthet Dent. 1981;46(4):443-9.

75. Yoon HR, Choi YJ, Kim KH, Chung C. Comparisons of occlusal force according to occlusal relationship, skeletal pattern, age and gender in Koreans. Korean J Orthod. 2010;40(5):304-13.

76. Watanabe-Kanno GA, Abrão J. Study of the number of occlusal contacts in maximum intercuspation before orthodontic treatment in subjects with Angle Class I and Class II division 1 malocclusion. Dental Press J Orthod. 2012;17(1):138-47.

77. Helkimo E, Carlsson GE, Helkimo M. Bite force and state of dentition. Acta odontol Scand. 1977;35(6):297-303.

78. Kiliaridis S, Kjellberg H, Wenneberg B, Engström C. The relationship between maximal bite force, bite force endurance, and facial morphology during growth: A cross-sectional study. Acta odontol Scand. 1933;51(5):323-31.

79. Lindauer S, Gay T, Rendell J. Effect of jaw opening on masticatory muscle EMG-force characteristics. J Dent Res. 1993;72(1):51-5.

80. Braun S, Hnat WP, Freudenthaler JW, Marcotte MR, Hönigle K, Johnson BE. A study of maximum bite force during growth and development. Angle Orthod. 1996;66(4):261-4.

81. Ortuğ G. A new device for measuring mastication force (Gnathodynamometer). Ann Anat. 2002;184(4):393-6.

82. Burke RE, Levine DN, Tsairis P, Zajac FE. Physiological types and histochemical profiles in motor units of the cat gastrocnemius. J Physiol. 1973;234(3):723-48.

83. Braun S, Bantleon HP, Hnat WP, Freudenthaler JW, Marcotte MR, Johnson BE. A study of bite force, part 2: Relationship to various cephalometric measurements. Angle Orthod. 1995;65(5):373-7.

84. Sondang P, Kumagai H, Tanaka E, Ozaki H, Nikawa H, Tanne K, et al. Correlation between maximum bite force and craniofacial morphology of young adults in Indonesia. J Oral Rehabil. 2003;30(11):1109-17.

85. Fernandes CP, Glantz PO, Svensson SA, Bergmark A. A novel sensor for bite force determinations. Dent Mater. 2003;19(2):118-26.

86. Mansour RM, Reynik RJ. In vivo occlusal forces and moments: I. Forces measured in terminal hinge position and associated moments. J Dent Res. 1975;54(1):114-20.

87. Hagberg C. Assessments of bite force: a review. J Craniomandib Disord. 1987;1(3):162-9.

88. Van Eijden TM, Brugman P, Weijs WA, Oosting J. Coactivation of jaw muscles: recruitment order and level as a function of bite force direction and magnitude. J Biomech. 1990;23(5):475-85.

89. Bakke M. Bite force and occlusion. Seminars in Orthodontics. 2006;12(2):120-6.

90. Mao J, Osborn JW. Direction of a bite force determines the pattern of activity in jaw-closing muscles. J Dent Res. 1994;73(5):1112-20.

91. Lee SM, Lee JW. Computerized occlusal analysis: correlation with occlusal indexes to assess the outcome of orthodontic treatment or the severity of malocculusion. Korean J Orthod. 2016;46(1):27-35.

92. Koos B, Godt A, Schille C, Goz G. Precision of an instrumentationbased method of analyzing occlusion and its resulting distribution of forces in the dental arch. J Orofac Orthop. 2010;71(6):403-10.

93. Kim J. Computerized occlusion using T-Scan III. South Boston (MA): Tekscan, Inc; 2014.

94. Maness WL, Podoloff R. Distribution of occlusal contacts in maximum intercuspation. The J Prosthet Dent. 1989;62(2):238-42.

95. Garrido García VC1, García Cartagena A, González Sequeros O. Evaluation of occlusal contacts in maximum intercuspation using the T-Scan system. J Oral Rehabil. 1997;24(12):899-903.

96. Kerstein RB, Lowe M, Harty M, Radke J. A force reproduction analysis of two recording sensors of a computerized occlusal analysis system. Cranio. 2006;24(1):15-24.

97. Maness WL, Benjamin M, Podoloff R, Bobick A, Golden RF. Computerized occlusal analysis: a new technology. Quintessence Int. 1987;18(4):287-92.

98. Kerstein RB. Handbook of research on computerized occlusal analysis technology applications in dental medicine. 1st ed. Hershey (PA): IGI Global; 2014.

99. Lila-Krasniqi ZD, Shala KSh, Pustina-Krasniqi T, Bicaj T, Dula LJ, Guguvčevski L. Differences between centric relation and maximum intercuspation as possible cause for development of temporomandibular disorder analyzed with T-scan III. Eur J Dent. 2015;9(4):573-9.

100. Wang YL, Cheng J, Chen YM, Yip KK, Smales R, Yin XM. Patterns and forces of occlusal contacts during lateral excursions recorded by the T-Scan II system in young Chinese adults with normal occlusions. J Oral Rehabil. 2011;38(8):571-8.

101. Nishi SE, Basri R, Alam MK, Komatsu S, Komori A, Sugita Y, et al. Evaluation of masticatory muscles function in different malocclusion cases using surface electromyography. J Hard Tissue Biol. 2017;26(1):23-8.

102. Jankulovka V, Jankulovska E, Petrova V, Kjurchieva-Chuchkova G, Kanurkova L, Petrova E, et al. Masticatory performance in subjects with Class II treated with myofunctional appliances: a review. IOSR J Dent Med Sci. 2017;16(4):50-3.

103. Agbaje JO, Van de Casteele E, Salem AS, Anumendem D, Shaheen E, Sun Y, et al. Assessment of occlusion with the T-Scan system in patients undergoing orthognathic surgery. Sci Rep. 2017;7(1):5356

104. Trpevska V, Kovacevska G, Benedetti A, Kanurkova L. Occlusion timeline analyses with T-Scan III system in subjects with neutroocclusion. Int J Sci Res. 2017;6(3):66-9.

105. Mizui M, Nabeshima F, Tosa J, Tanaka M, Kawazoe, T. Quantitative analysis of occlusal balance in intercuspal position using the TScan system. Int J Prosthodont. 1994;7(1):62-71.

106. Wang C, Yin X. Occlusal risk factors associated with temporomandibular disorders in young adults with normal occlusions. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012;114(4):419-23.

107. Kerstein RB. Disclusion time measurement studies: a comparison of disclusion time between chronic myofascial pain dyfunction patients and nonpatients: a population analysis. J Prosthet Dent. 1994;72(5):473-80.

108. Kerstein RB. A comparison of traditional occlusal equilibration and immediate complete anterior guidance development. Cranio. 1993;11(2):126-39.

109. Henrikson T, Nilner M, Kurol J. Signs of temporomandibular disorders in girls receiving orthodontic treatment. A prospective and longitudinal comparison with untreated Class II malocclusions and normal occlusion subjects. Eur J Orthod. 2000;22(3):271-81.

110. Cochran WG. Sampling techniques. 3rd ed. Ontario (Canada): John Wiley & Sons; 1977.

111. Kerstein RB. T-Scan III applications in mixed arch and complete arch, implant-supported prosthodontics. Dent Implantol Update. 2008;19(7):49-53.

112. Qadeer S, Abbas AA, Sarinnaphakorn L, Kerstein RB. Comparison of excursive occlusal force parameters in post-orthodontic and non-orthodontic subjects using T-Scan® III. Cranio. 2018;36(1):11-8.

113. Haralur SB. Digital evaluation of functional occlusion parameters and their association with temporomandibular disorders. J Clin Diagn Res. 2013;7(8):1772-5.

114. Afrashtehfa KI, Qadeer S. Computerized occlusal analysis as an alternative occlusal indicator. Cranio. 2016;34(1):52-7.

115. Angle EH. Classification of malocclusion. Dent Cosmos. 1899;41:248-64.

116. Maness WL. Laboratory comparison of three occlusal registration methods for identification of induced interceptive contacts. J Prosthet Dent. 1991;65(4):483-7.

117. Mitchem JA, Katona TR, Moser EAS. Does the presence of an occlusal indicator product affect the contact forces between full dentitions?. J Oral Rehabil. 2017;44(10):791-9.

118. Sutter BA. A digital poll of dentists testing the accuracy of paper mark subjective interpretation. Cranio. 2018;36(6):396-403.

119. Qadeer S. The limitations of traditional non digital occlusal indicators when compared to T-Scan computerized occlusal analysis. In: Kerstein RB, editor. Handbook of research: computerized occlusal analysis technology applications in dental medicine. IGI Global; 2015. p. 36-65.

120. Qadeer S, Yang L, Sarinnaphakorn L, Kerstein RB. Comparison of closure occlusal force parameters in post-orthodontic and non-orthodontic subjects using T-Scan® III DMD occlusal analysis. Cranio. 2016;34(6):395-401.

121. Seth V, Patil AK, Kidiyoor H, Patil K. T Scan–An aid in achieving stable occlusion during finishing stages of orthodontic treatment. Int J Stomatol Occlusion Med. 2016;8(1):30-6.

122. Roldán SI, Restrepo LG, Isaza JF, Vélez LG, Buschang PH. Are maximum bite forces of subjects 7 to 17 years of age related to malocclusion?. Angle Orthod. 2016;86(3):456-61.

123. Bae J, Son WS, Kim SS, Park SB, Kim YI. Comparison of masticatory efficiency according to Angle's classification of malocclusion. Korean J Orthod. 2017;47(3):151-7.

124. English JD, Buschang PH, Throckmorton GS. Does malocclusion affect masticatory performance?. Angle Orthod. 2002;72(1):21-7.

125. Runge ME, Sadowsky C, Sakols EI, BeGole EA. The relationship between temporomandibular joint sounds and malocclusion. Am J Orthod Dentofacial Orthop. 1989;96(1):36-42.

126. Seligman DA, Pullinger AC. The role of intercuspal occlusal relationships in temporomandibular disorders: a review. J Craniomandib Disord. 1991;5(4):265-79.

127. Mohlin BO, Derweduwen K, Pilley R, Kingdon A, Shaw WC, Kenealy P. Malocclusion and temporomandibular disorder: a comparison of adolescents with moderate to severe dysfunction with those without signs and symptoms of temporomandibular disorder and their further development to 30 years of age. Angle Orthod. 2004;74(3):319-27.

128. Shin JH, Kwon JS, Kim ST, Park HU, Choi JH. Study of disclusion time during mandibular eccentric movement in myofascial pain syndrome patients by T-Scan II, computerized occlusal analysis system. J Oral Med Pain. 2011;36(3):187-97.

129. Thumati P, Manwani R, Mahantshetty M. The effect of reduced disclusion time in the treatment of myofascial pain dysfunction syndrome using immediate complete anterior guidance development protocol monitored by digital analysis of occlusion. Cranio. 2014;32(4):289-99.

130. Al-Hiyasat AS, Abu-Alhaija ES. The relationship between static and dynamic occlusion in 14–17-year-old school children. J Oral Rehabil. 2004;31(7):628-33.

131. Stringert HG, Worms FW. Variations in skeletal and dental patterns in patients with structural and functional alterations of the temporomandibular joint: a preliminary report. Am J Orthod. 1986;89(4):285-97.

132. Hwang CJ, Sung SJ, Kim SJ. Lateral cephalometric characteristics of malocclusion patients with temporomandibular joint disorder symptoms. Am J Orthod Dentofacial Orthop. 2006;129(4):497-503.

133. Almăşan OC, Băciuţ M, Almăşan HA, Bran S, Lascu L, Iancu M, et al. Skeletal pattern in subjects with temporomandibular joint disorders. Arch Med Sci. 2013;9(1):118-26.

APPENDICES

Appendix A: The protocol approved by Naresuan University Institutional Review Board

COA No. 601/2017
IRB No. 0721/60

คณะกรรมการจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยนเรศวร
NARESUAN UNIVERSITY INSTITUTIONAL REVIEW BOARD
99 หมู่ 9 ตำบลท่าโพธิ์ อำเภอเมือง จังหวัดพิษณุโลก 65000 เบอร์โทรศัพท์ 05596 8642

เอกสารรับรองโครงการวิจัย

คณะกรรมการจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยนเรศวร ดำเนินการให้การรับรองโครงการวิจัยตามแนวทางหลักจริยธรรมการวิจัยในคนที่เป็นมาตรฐานสากล ได้แก่ Declaration of Helsinki, The Belmont Report, CIOMS Guideline และ International Conference on Harmonization in Good Clinical Practice หรือ ICH-GCP

ชื่อโครงการ	: การกระจายแรงบดเคี้ยวและเวลาการสบแยก ในการสบฟันที่ผิดปกติแต่ละประเภทตาม : การจำแนกของแองเกิล: การประเมินโดยใช้ระบบทีสแกน ๓
Study Title	: Occlusal Force Distributions and Dental Disclusion Time in Angle's : Malocclusion: an Evaluation by the T-Scan III System.
ผู้วิจัยหลัก	: นางสาวฐิติรัตน์ ฉัตรเฉลิมพันธุ์
Principal Investigator	: Miss Titirat Chutchalermpan
สังกัดหน่วยงาน	: คณะทันตแพทยศาสตร์
วิธีทบทวน	: แบบเร่งรัด (Expedited Review)
รายงานความก้าวหน้า	: ส่งรายงานความก้าวหน้าอย่างน้อย 1 ครั้ง/ปี หรือส่งรายงานฉบับสมบูรณ์หากดำเนินโครงการเสร็จสิ้นก่อน 1 ปี

เอกสารรับรอง

1. AF 01-10 เวอร์ชั่น 2.0 วันที่ 17 ตุลาคม 2560
2. AF 02-10 เวอร์ชั่น 2.0 วันที่ 17 ตุลาคม 2560
3. AF 03-10 เวอร์ชั่น 1.0 วันที่ 13 กันยายน 2560
4. AF 04-10 เวอร์ชั่น 2.0 วันที่ 17 ตุลาคม 2560
5. AF 05-10 เวอร์ชั่น 2.0 วันที่ 17 ตุลาคม 2560
6. สรุปโครงการเพื่อการพิจารณาทางจริยธรรมการวิจัยในมนุษย์ เวอร์ชั่น 2.0 วันที่ 17 ตุลาคม 2560
7. โครงร่างงานวิจัย เวอร์ชั่น 1.0 วันที่ 13 กันยายน 2560
8. ประวัติผู้วิจัย เวอร์ชั่น 1.0 วันที่ 13 มิถุนายน 2560
9. งบประมาณที่ได้รับโดยย่อ เวอร์ชั่น 1.0 วันที่ 13 มิถุนายน 2560
10. รายละเอียดเครื่องมือที่ใช้ในการวิจัย เวอร์ชั่น 1.0 วันที่ 13 มิถุนายน 2560

ลงนาม

(นายแพทย์สมบูรณ์ ต้นสุภสวัสดิกุล)
ประธานคณะกรรมการจริยธรรมการวิจัยในมนุษย์
มหาวิทยาลัยนเรศวร

วันที่รับรอง	: 01 พฤศจิกายน 2560
Date of Approval	: November 01, 2017
วันหมดอายุ	: 01 พฤศจิกายน 2561
Approval Expire Date	: November 01, 2018

ทั้งนี้ การรับรองนี้มีเงื่อนไขดังที่ระบุไว้ด้านหลังทุกข้อ (ดูด้านหลังของเอกสารรับรองโครงการวิจัย)

นักวิจัยทุกท่านที่ผ่านการรับรองจริยธรรมการวิจัยต้องปฏิบัติดังต่อไปนี้

1. ดำเนินการวิจัยตามที่ระบุไว้ในโครงการวิจัยอย่างเคร่งครัด
2. ใช้เอกสารแนะนำอาสาสมัคร ใบยินยอม (และเอกสารเชิญเข้าร่วมวิจัยหรือใบโฆษณาถ้ามี) แบบสัมภาษณ์ และหรือ แบบสอบถาม เฉพาะที่มีตราประทับของคณะกรรมการจริยธรรมในมนุษย์ มหาวิทยาลัยนเรศวรเท่านั้น
3. รายงานเหตุการณ์ไม่พึงประสงค์ร้ายแรงที่เกิดขึ้นหรือการเปลี่ยนแปลงกิจกรรมวิจัยใดๆ ต่อคณะกรรมการจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยนเรศวร ภายในระยะเวลาที่กำหนดในวิธีดำเนินการมาตรฐาน (SOPs)
4. ส่งรายงานความก้าวหน้าต่อคณะกรรมการจริยธรรมการวิจัยในมนุษย์ ตามเวลาที่กำหนดหรือเมื่อได้รับการร้องขอ
5. หากการวิจัยไม่สามารถดำเนินการเสร็จสิ้นภายในกำหนด ผู้วิจัยต้องยื่นขออนุมัติใหม่ก่อน อย่างน้อย 1 เดือน
6. หากผู้วิจัยส่งรายงานความก้าวหน้าหลังใบรับรองหมดอายุ และยังไม่ได้ใบรับรองฉบับใหม่ ผู้วิจัยจะต้องหยุดดำเนินการวิจัยส่วนที่เกี่ยวข้องกับการรับอาสาสมัครใหม่ นับตั้งแต่หลังวันใบรับรองหมดอายุจนกว่าจะได้รับใบรับรองฉบับใหม่
7. หากการวิจัยเสร็จสมบูรณ์ผู้วิจัยต้องแจ้งปิดโครงการตามแบบฟอร์มของคณะกรรมการจริยธรรมในมนุษย์ มหาวิทยาลัยนเรศวร

* รายชื่อของคณะกรรมการจริยธรรมการวิจัยในมนุษย์ (ชื่อและตำแหน่ง) ที่เข้าร่วมประชุม ณ วันที่พิจารณารับรองโครงการวิจัย (หากร้องขอล่วงหน้า)

Appendix B: Information sheet for research participant

AF 04-10/4.0

Naresuan University Institutional Review Board	ข้อมูลคำอธิบายสำหรับอาสาสมัครในโครงการวิจัย (Information Sheet for Research Participant)

ชื่อโครงการวิจัย การกระจายแรงบดเคี้ยวและเวลาการสบแยก ในการสบฟันที่ผิดปกติแต่ละประเภทตามการจำแนกของแองเกิล: การประเมินโดยใช้ระบบทีสแกน 3
(Occlusal Force Distributions and Dental Disclusion Time in Angle's Malocclusions: an Evaluation by the T-Scan III System)

ผู้สนับสนุนการวิจัย บัณฑิตศึกษา มหาวิทยาลัยนเรศวร

<u>ผู้ทำวิจัย</u>

ชื่อ ฐิติรัตน์ ฉัตรเฉลิมพันธุ์

ที่อยู่ หอพักเฟื่องฟ้า บ้านเลขที่ 156/43 หมู่ 8 ตำบลท่าโพธิ์ อำเภอเมือง จังหวัดพิษณุโลก 65000

เบอร์โทรศัพท์ 086-1363537 (มือถือ), 055-963730 ต่อ 6969 (ที่ทำงาน)

เรียน ผู้เข้าร่วมโครงการวิจัยทุกท่าน

ท่านได้รับเชิญให้เข้าร่วมในโครงการวิจัยนี้เนื่องจากท่านเป็น ผู้ป่วยที่จำเป็นต้องได้รับการตรวจภายนอกและภายในช่องปาก รวมถึงการประเมินการสบฟันและการบดเคี้ยว โดยการใช้ชุดตรวจฟัน เพื่อให้ได้ข้อมูลเบื้องต้นในการคัดกรองผู้ที่ผ่านเกณฑ์การคัดเข้า จากนั้นทำการบันทึกการสบฟันโดยการใช้เครื่องมือทีสแกน เพื่อทราบถึงการกระจายแรงบดเคี้ยวและระยะเวลาการสบแยกขณะที่มีการเคลื่อนขากรรไกรในแต่ละท่าน ก่อนที่ท่านจะตัดสินใจเข้าร่วมในการศึกษาวิจัยดังกล่าว ขอให้ท่านอ่านเอกสารฉบับนี้อย่างถี่ถ้วน เพื่อให้ท่านได้ทราบถึงเหตุผลและรายละเอียดของการศึกษาวิจัยในครั้งนี้ หากท่านมีข้อสงสัยใดๆ เพิ่มเติม กรุณาซักถามจากทีมงานของทันตแพทย์ผู้ทำวิจัย หรือทันตแพทย์ผู้ร่วมทำวิจัยซึ่งจะเป็นผู้สามารถตอบคำถามและให้ความกระจ่างแก่ท่านได้

ท่านสามารถขอคำแนะนำในการเข้าร่วมโครงการวิจัยนี้จากครอบครัว เพื่อน หรือทันตแพทย์ประจำตัวของท่านได้ ท่านมีเวลาอย่างเพียงพอในการตัดสินใจโดยอิสระ ถ้าท่านตัดสินใจแล้วว่าจะเข้าร่วมในโครงการวิจัยนี้ ขอให้ท่านลงนามในเอกสารแสดงความยินยอมของโครงการวิจัยนี้

<u>เหตุผลความเป็นมา</u>

การสบฟันที่ปกติเป็นหนึ่งในเป้าหมายที่สำคัญในการรักษาทางทันตกรรมจัดฟัน ทั้งนี้การสบฟันที่ผิดปกติอาจเป็นปัจจัยหนึ่งที่ทำให้เกิดโรคความผิดปกติของข้อต่อขากรรไกร อย่างไรก็ตามความสัมพันธ์ระหว่างปัจจัยที่เกี่ยวข้องกับการสบฟันและโรคความผิดปกติของข้อต่อขากรรไกรยังไม่มีข้อสรุปที่ชัดเจน นอกจากนี้การสบฟันที่ผิดปกติอาจส่งผลให้เกิดการกระจายแรงบดเคี้ยวที่ไม่สมดุลและมีระยะเวลาการสบแยกที่นานกว่าค่าปกติ

ปัจจุบันระบบทีสแกนเป็นเทคโนโลยีใหม่ที่ให้ข้อมูลทางด้านการสบฟันและลดข้อจำกัดที่ไม่สามารถทำได้ในวิธีดั้งเดิม โดยมีการพัฒนาเป็นระบบทีสแกน 3 ซึ่งสามารถให้การวิเคราะห์การสบฟันแบบพลวัตซึ่งความความแม่นยำสูง

ดังนั้นความสำคัญของการรักษาทางทันตกรรมจัดฟันเพื่อให้ได้การสบฟันที่ปกติด้วยเหตุผลดังกล่าว จึงนำมาสู่งานวิจัยนี้ เพื่อเป็นข้อมูลให้ผู้ป่วยทราบถึงผลของการสบฟันที่ผิดปกติ รวมถึงเป็นข้อมูลที่แสดงให้เห็นถึงประโยชน์และความจำเป็นในการจัดฟันให้มีการสบฟันที่ปกติ โดยมีเป้าหมายเพื่อเปรียบเทียบและประเมินการกระจายแรงบดเคี้ยวและระยะเวลาการสบแยก ในการสบฟันที่ผิดปกติตามการจำแนกของแองเกิล โดยการใช้เครื่องทีสแกน 3

<u>วัตถุประสงค์ของการศึกษา</u>

1. เพื่อเปรียบเทียบการกระจายแรงบดเคี้ยวไปตามส่วนโค้งขากรรไกรบนที่ตำแหน่งที่มีการสบฟันมากสุด ในผู้ป่วยที่มีการสบฟันที่ผิดปกติตามการจำแนกของแองเกิล โดยการใช้เครื่องมือทีสแกน 3
2. เพื่อเปรียบเทียบเวลาการสบแยก ขณะเคลื่อนขากรรไกรไปด้านด้านหน้าและทางด้านข้าง ในผู้ป่วยที่มีการสบฟันที่ผิดปกติตามการจำแนกของแองเกิล โดยการใช้เครื่องมือทีสแกน 3

<u>วิธีการที่เกี่ยวข้องกับการวิจัย</u>

หลังจากท่านให้ความยินยอมที่จะเข้าร่วมในโครงการวิจัยนี้ ผู้วิจัยจะขอตรวจระบบข้อต่อขากรรไกรและกล้ามเนื้อบดเคี้ยว รวมถึงการตรวจช่องปาก เพื่อคัดกรองว่าท่านมีคุณสมบัติที่เหมาะสมที่จะเข้าร่วมในการวิจัย หากท่านมีคุณสมบัติตามเกณฑ์คัดเข้า ท่านจะได้รับเชิญให้มาพบแพทย์ตามวันเวลาที่ผู้ทำวิจัยนัดหมาย และมาพบผู้วิจัยหรือผู้ร่วมทำวิจัยทั้งสิ้น 1 ครั้ง เพื่อบันทึกการสบฟันโดยการใช้เครื่องมือทีสแกนซึ่งจะใช้เวลาในการตรวจและวิเคราะห์ 15 นาที โดยมีอาสาสมัครที่เข้าร่วมในโครงการวิจัยทั้งหมด 100 คน

<u>ความรับผิดชอบของอาสาสมัครผู้เข้าร่วมในโครงการวิจัย</u>

เพื่อให้งานวิจัยนี้ประสบความสำเร็จ ผู้ทำวิจัยใคร่ขอความความร่วมมือจากท่าน โดยจะขอให้ท่านปฏิบัติตามคำแนะนำของผู้ทำวิจัยอย่างเคร่งครัด รวมทั้งแจ้งอาการผิดปกติต่าง ๆ ที่เกิดขึ้นกับท่านระหว่างที่ท่านเข้าร่วมในโครงการวิจัยให้ผู้ทำวิจัยได้รับทราบ

<u>ความเสี่ยงที่อาจได้รับ</u>

ไม่มีความเสี่ยงจากการเข้าร่วมงานวิจัยนี้ เนื่องจากเป็นเพียงการบันทึกการสบฟันโดยกัดฟันบนเครื่องมือทีสแกนเท่านั้น

<u>ประโยชน์ที่อาจได้รับ</u>

ท่านจะไม่ได้รับประโยชน์ใดๆจากการเข้าร่วมในการวิจัยครั้งนี้ แต่ผลการศึกษาที่ได้จะนำไปใช้พิจารณาถึงแนวทางการรักษาทางทันตกรรมจัดฟัน รวมถึงเป็นแนวทางการทำวิจัยต่อไป

<u>วิธีการและรูปแบบการรักษาอื่น ๆ ซึ่งมีอยู่สำหรับอาสาสมัคร</u>

ท่านไม่จำเป็นต้องเข้าร่วมโครงการวิจัยนี้เพื่อประโยชน์ในการรักษาโรคที่ท่านเป็นอยู่ เนื่องจากมีแนวทางการรักษาอื่น ๆ หลายแบบสำหรับรักษาโรคของท่านได้ ดังนั้นจึงควรปรึกษาแนวทางการรักษาวิธีอื่นๆ กับทันตแพทย์ผู้ให้การรักษาท่านก่อนตัดสินใจเข้าร่วมในการวิจัย

<u>ข้อปฏิบัติของท่านขณะที่ร่วมในโครงการวิจัย</u>

ขอให้ท่านปฏิบัติดังนี้

- **ขอให้ท่านให้ข้อมูลทางการแพทย์ของท่านทั้งในอดีต และปัจจุบัน แก่ผู้ทำวิจัยด้วยความสัตย์จริง**
- **ขอให้ท่านแจ้งให้ผู้ทำวิจัยทราบความผิดปกติที่เกิดขึ้นระหว่างที่ท่านร่วมในโครงการวิจัย**

<u>อันตรายที่อาจเกิดขึ้นจากการเข้าร่วมในโครงการวิจัยและความรับผิดชอบของผู้ทำวิจัย/ผู้สนับสนุนการวิจัย</u>

หากพบอันตรายที่เกิดขึ้นจากการวิจัย ท่านจะได้รับการรักษาอย่างเหมาะสมทันที และท่านปฏิบัติตามคำแนะนำของทีมผู้ทำวิจัยแล้ว ผู้ทำวิจัย/ผู้สนับสนุนการวิจัยยินดีจะรับผิดชอบค่าใช้จ่ายในการรักษาพยาบาลของท่าน และการลงนามในเอกสารให้ความยินยอม ไม่ได้หมายความว่าท่านได้สละสิทธิ์ทางกฎหมายตามปกติที่ท่านพึงมี

ในกรณีที่ท่านได้รับอันตรายใด ๆ หรือต้องการข้อมูลเพิ่มเติมที่เกี่ยวข้องกับโครงการวิจัย ท่านสามารถ ติดต่อกับผู้ทำวิจัยคือ ทันตแพทย์หญิงฐิติรัตน์ ฉัตรเฉลิมพันธุ์ โทร 086-1363537 ได้ตลอด 24 ชั่วโมง

<u>ค่าใช้จ่ายของท่านในการเข้าร่วมการวิจัย</u>

ไม่มีค่าใช้จ่ายเพิ่มเติมนอกเหนือจากค่าใช้จ่ายตามการรักษาตามปกติ

<u>การเข้าร่วมและการสิ้นสุดการเข้าร่วมโครงการวิจัย</u>

การเข้าร่วมในโครงการวิจัยครั้งนี้เป็นไปโดยความสมัครใจ หากท่านไม่สมัครใจจะเข้าร่วมการศึกษาแล้ว ท่านสามารถถอนตัวได้ตลอดเวลา การขอถอนตัวออกจากโครงการวิจัยจะไม่มีผลต่อการดูแลรักษาโรคของท่านแต่อย่างใด

ผู้ทำวิจัยอาจถอนท่านออกจากการเข้าร่วมการวิจัย เพื่อเหตุผลด้านความปลอดภัยของท่าน หรือเมื่อผู้สนับสนุนการวิจัยยุติการดำเนินงานวิจัย หรือ ในกรณีดังต่อไปนี้

- ท่านตั้งครรภ์ระหว่างที่เข้าร่วมโครงการวิจัย

<u>การปกป้องรักษาข้อมูลความลับของอาสาสมัคร</u>

ข้อมูลที่อาจนำไปสู่การเปิดเผยตัวท่าน จะได้รับการปกปิดและจะไม่เปิดเผยแก่สาธารณชน ในกรณีที่ผลการวิจัยได้รับการตีพิมพ์ ชื่อและที่อยู่ของท่านจะต้องได้รับการปกปิดอยู่เสมอ โดยจะใช้เฉพาะรหัสประจำโครงการวิจัยของท่าน ทั้งนี้ ข้อมูลของท่านจะถูกจัดเก็บ 10 ปี เพราะเป็นข้อมูลที่สามารถเห็นสภาพฟันโดยรวมได้ชัดเจนซึ่งอาจจะมีประโยชน์เชิงงานวิจัยต่อยอดจากวิจัยนี้ สถานที่เก็บ คณะทันตแพทยศาสตร์ มหาวิทยาลัยนเรศวร แบบจำลองฟันจะถูกทำลายโดยทำให้แตกละเอียดและทิ้งถังขยะในปี 2570

จากการลงนามยินยอมของท่าน ผู้ทำวิจัยและผู้สนับสนุนการวิจัยไม่สามารถเข้าไปตรวจสอบบันทึกข้อมูลการรักษาของท่านได้แม้จะสิ้นสุดโครงการวิจัยแล้วก็ตาม เนื่องจากมีการบันทึกข้อมูลการรักษาของท่าน แต่ไม่ได้ระบุตัวตนของท่านผู้เข้าร่วมวิจัย

หากท่านขอยกเลิกการให้คำยินยอมหลังจากที่ท่านได้เข้าร่วมโครงการวิจัยแล้ว ข้อมูลส่วนตัวของท่านจะไม่ถูกบันทึกเพิ่มเติม อย่างไรก็ตามข้อมูลอื่น ๆ ของท่านอาจถูกนำมาใช้เพื่อประเมินผลการวิจัย และท่านจะไม่สามารถกลับมาเข้าร่วมในโครงการนี้ได้อีก ทั้งนี้เนื่องจากข้อมูลของท่านที่จำเป็นสำหรับใช้เพื่อการวิจัยไม่ได้ถูกบันทึก

จากการลงนามยินยอมของท่าน ทันตแพทย์ผู้ทำวิจัยสามารถบอกรายละเอียดของท่านที่เกี่ยวกับการเข้าร่วมโครงการวิจัยนี้ให้แก่ทันตแพทย์แพทย์ผู้รักษาท่านได้

<u>สิทธิ์ของผู้เข้าร่วมในโครงการวิจัย</u>

ในฐานะที่ท่านเป็นผู้เข้าร่วมในโครงการวิจัย ท่านจะมีสิทธิ์ดังต่อไปนี้

1. ท่านจะได้รับทราบถึงลักษณะและวัตถุประสงค์ของการวิจัยในครั้งนี้
2. ท่านจะได้รับการอธิบายเกี่ยวกับระเบียบวิธีการของการวิจัยทางการแพทย์ รวมทั้งยาและอุปกรณ์ที่ใช้ในการวิจัยครั้งนี้
3. ท่านจะได้รับการอธิบายถึงความเสี่ยงและความไม่สบายที่จะได้รับจากการวิจัย
4. ท่านจะได้รับการอธิบายถึงประโยชน์ที่ท่านอาจจะได้รับจากการวิจัย
5. ท่านจะได้รับการเปิดเผยถึงทางเลือกในการรักษาด้วยวิธีอื่น ยา หรืออุปกรณ์ซึ่งมีผลดีต่อท่านรวมทั้งประโยชน์และความเสี่ยงที่ท่านอาจได้รับ
6. ท่านจะได้รับทราบแนวทางในการรักษา ในกรณีที่พบโรคแทรกซ้อนภายหลังการเข้าร่วมในโครงการวิจัย
7. ท่านจะมีโอกาสได้ซักถามเกี่ยวกับงานวิจัยหรือขั้นตอนที่เกี่ยวข้องกับงานวิจัย
8. ท่านจะได้รับทราบว่าการยินยอมเข้าร่วมในโครงการวิจัยนี้ ท่านสามารถขอถอนตัวจากโครงการเมื่อไรก็ได้ โดยผู้เข้าร่วมในโครงการวิจัยสามารถขอถอนตัวจากโครงการโดยไม่ได้รับผลกระทบใด ๆ ทั้งสิ้น
9. ท่านจะได้รับเอกสารข้อมูลคำอธิบายสำหรับผู้เข้าร่วมในโครงการวิจัยและสำเนาเอกสารใบยินยอมที่มีทั้งลายเซ็นและวันที่
10. ท่านมีสิทธิ์ในการตัดสินใจว่าจะเข้าร่วมในโครงการวิจัยหรือไม่ก็ได้ โดยปราศจากการใช้อิทธิพลบังคับข่มขู่ หรือการหลอกลวง

หากท่านไม่ได้รับการชดเชยอันควรต่อการบาดเจ็บหรือเจ็บป่วยที่เกิดขึ้นโดยตรงจากการวิจัย หรือท่านไม่ได้รับการปฏิบัติตามที่ปรากฏในเอกสารข้อมูลคำอธิบายสำหรับผู้เข้าร่วมในการวิจัย ท่านสามารถร้องเรียนได้ที่ สำนักงานคณะกรรมการจริยธรรมการวิจัยในมนุษย์ มหาวิทยาลัยนเรศวร กองบริหารการวิจัย ชั้น 2 อาคารมหาธรรมราชา มหาวิทยาลัยนเรศวร อำเภอเมือง จังหวัดพิษณุโลก 65000 หมายเลขโทรศัพท์ 055968642 หมายเลขโทรสาร 055968637 ในเวลาราชการ หรือ e-mail : NU-IRB@nu.ac.th

ขอขอบคุณในการร่วมมือของท่านมา ณ ที่นี้

Appendix C: Informed consent form

AF 05-10/4.0

Naresuan University Institutional Review Board	หนังสือแสดงความยินยอมเข้าร่วมโครงการวิจัย (Informed Consent Form)

การวิจัยเรื่อง การกระจายแรงบดเคี้ยวและเวลาการแยกแยก ในการสบฟันที่ผิดปกติแต่ละประเภทตามการจำแนกของแองเกิล: การประเมินโดยใช้ระบบทีสแกน 3

วันให้คำยินยอม วันที่..........**เดือน**...............................**พ.ศ.**...

ข้าพเจ้า นาย/นาง/นางสาว..ที่อยู่ ....ได้อ่านรายละเอียดจากเอกสารข้อมูลสำหรับผู้เข้าร่วมโครงการวิจัยวิจัยที่แนบมาฉบับวันที่.............................. และข้าพเจ้ายินยอมเข้าร่วมโครงการวิจัยโดยสมัครใจ

ข้าพเจ้าได้รับสำเนาเอกสารแสดงความยินยอมเข้าร่วมในโครงการวิจัยที่ข้าพเจ้าได้ลงนาม และ วันที่ พร้อมด้วยเอกสารข้อมูลสำหรับผู้เข้าร่วมโครงการวิจัย ทั้งนี้ก่อนที่จะลงนามในใบยินยอมให้ทำการวิจัยนี้ ข้าพเจ้าได้รับการอธิบายจากผู้วิจัยถึงวัตถุประสงค์ของการวิจัย ระยะเวลาของการทำวิจัย วิธีการวิจัย อันตราย หรืออาการที่อาจเกิดขึ้นจากการวิจัย รวมทั้งประโยชน์ที่จะเกิดขึ้นจากการวิจัย ข้าพเจ้ามีเวลาและโอกาสเพียงพอในการซักถามข้อสงสัยจนมีความเข้าใจอย่างดีแล้ว โดยผู้วิจัยได้ตอบคำถามต่าง ๆ ด้วยความเต็มใจไม่ปิดบังซ่อนเร้นจนข้าพเจ้าพอใจ

ข้าพเจ้ารับทราบจากผู้วิจัยว่าหากเกิดอันตรายใด ๆ จากการวิจัยดังกล่าว ข้าพเจ้าจะได้รับการรักษาพยาบาลโดยไม่เสียค่าใช้จ่าย และจะได้รับการชดเชยจากผู้สนับสนุนการวิจัยตามสมควร

ข้าพเจ้ามีสิทธิที่จะบอกเลิกเข้าร่วมในโครงการวิจัยเมื่อใดก็ได้ โดยไม่จำเป็นต้องแจ้งเหตุผล และการบอกเลิกการเข้าร่วมการวิจัยนี้

ผู้วิจัยรับรองว่าจะเก็บข้อมูลส่วนตัวของข้าพเจ้าเป็นความลับ และจะเปิดเผยได้เฉพาะเมื่อได้รับการยินยอมจากข้าพเจ้าเท่านั้น คณะกรรมการพิจารณาจริยธรรมการวิจัยในคน สำนักงานคณะกรรมการอาหารและยาอาจได้รับอนุญาตให้เข้ามาตรวจและประมวลข้อมูลของข้าพเจ้า ทั้งนี้จะต้องกระทำไปเพื่อวัตถุประสงค์เพื่อตรวจสอบความถูกต้องของข้อมูลเท่านั้น

ผู้วิจัยรับรองว่าจะไม่มีการเก็บข้อมูลใด ๆ เพิ่มเติม หลังจากที่ข้าพเจ้าขอยกเลิกการเข้าร่วมโครงการวิจัยและต้องการให้ทำลายเอกสารและ/หรือ ตัวอย่างที่ใช้ตรวจสอบทั้งหมดที่สามารถสืบค้นถึงตัวข้าพเจ้าได้

ข้าพเจ้าเข้าใจว่า ข้าพเจ้ามีสิทธิ์ที่จะตรวจสอบหรือแก้ไขข้อมูลส่วนตัวของข้าพเจ้าและสามารถยกเลิกการให้สิทธิในการใช้ข้อมูลส่วนตัวของข้าพเจ้าได้ โดยต้องแจ้งให้ผู้วิจัยรับทราบ

ข้าพเจ้าได้ตระหนักว่าข้อมูลในการวิจัยรวมถึงข้อมูลทางการแพทย์ของข้าพเจ้าที่ไม่มีการเปิดเผยชื่อ จะผ่านกระบวนการต่าง ๆ เช่น การเก็บข้อมูล การบันทึกข้อมูลในแบบบันทึกและในคอมพิวเตอร์ การตรวจสอบ การวิเคราะห์ และการรายงานข้อมูลเพื่อวัตถุประสงค์ทางวิชาการเท่านั้น

ข้าพเจ้าได้อ่านข้อความข้างต้นและมีความเข้าใจดีทุกประการแล้ว ยินดีเข้าร่วมในการวิจัยด้วยความเต็มใจ จึงได้ลงนามในเอกสารแสดงความยินยอมนี้

....ลงนามผู้ให้ความยินยอม

(..) ชื่อผู้ยินยอมตัวบรรจง

วันที่ ....เดือน....................................พ.ศ...........................

ข้าพเจ้าได้อธิบายถึงวัตถุประสงค์ของการวิจัย วิธีการวิจัย อันตราย หรืออาการไม่พึงประสงค์หรือความเสี่ยงที่อาจเกิดขึ้นจากการวิจัย รวมทั้งประโยชน์ที่จะเกิดขึ้นจากการวิจัยอย่างละเอียด ให้ผู้เข้าร่วมในโครงการวิจัยตามนามข้างต้นได้ทราบและมีความเข้าใจดีแล้ว พร้อมลงนามลงในเอกสารแสดงความยินยอมด้วยความเต็มใจ

....ลงนามผู้ทำวิจัย

(ทันตแพทย์หญิงฐิติรัตน์ ฉัตรเฉลิมพันธุ์)

วันที่ ....เดือน....................................พ.ศ...........................

....ลงนามพยาน

(..) ชื่อพยาน ตัวบรรจง

วันที่ ....เดือน....................................พ.ศ...........................