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Treatment Outcomes utilizing TADs for Mandibular Dental Distalization

by

Jesus I. Patino Jr., DDS

THESIS

Submitted in partial satisfaction of the requirements for the degree of

MASTER OF SCIENCE

in

Oral and Craniofacial Sciences

in the

GRADUATE DIVISION

of the

UNIVERSITY OF CALIFORNIA, SAN FRANCISCO

DEDICATION

I would like to dedicate this Master's Thesis to my loving, caring, and supportive family. To my father who taught me to never cut corners and to always work hard for my future. To my mother who taught me to treat others as I would like to be treated and her never ending love. To my big sister who would always watch over me. You three have shaped me into the person I am today.

ACKNOWLEDGEMENTS

I would like to thank a few special people that contributed to the completion of my thesis. I would like to thank Dr. James Chen, who approached me with this idea and traveled to Taiwan to collect the data. His selfless work and mentorship has provided me with the means to complete this thesis. My colleagues in Taiwan who helped collect all the data from their records, Dr. Jenny Zwei-Chieng Chang and Dr. Jane Chung-Chen Yao. I would like to thank Dr. Ib Nielsen, whose undeniable understanding of lateral ceph super imposition and mandibular growth helped me further interpret my data. Also, I greatly appreciate Dr. Jens Bjørn Jørgensen who modified his TIOPs program for my investigation specifically. I would also like to thank Dr. Art Miller, whose genuine kindness and support helped me overcome hurdles that I met while completing my thesis. I greatly appreciate the help and patience of Nancy Hills who provided me with all the statistical interpretation of my data. Finally, to all of my orthodontic faculty that have provided me with the solid foundation of both the scientific and the clinical understanding of orthodontics that will be with me for the rest of my career.

Treatment Outcomes utilizing TADs for Mandibular Dental Distalization.

by

Jesus I. Patiño Jr., DDS

ABSTRACT

Purpose: The purpose of this investigation was to: 1) use the peer assessment rating (PAR), the index of complexity, outcome, and need (ICON), and the American Board of Orthodontics objective grading system (ABO-OGS) indices to access the quality of completed orthodontic treatment using temporary skeletal anchorage devices (TSAD) to distalize the mandibular dentition in Class III non-growing patients; 2) to evaluate the dental movement of the mandibular first molars, second premolars, and incisors between subjects; and 3) to identify predictable characteristics in pretreatment subjects that resulted in greater dental movement.

Methods: Subjects were evaluated who finished mandibular demtal distalization treatment using TSAD anchorage in the last 5-yrs from the Department of Orthodontics and Dentofacial Orthopedics and Oral Biology at the National Taiwan University. A total of 27 subjects (14 males, 13 females) met this requirement, but only 20 subjects (10 females, 10 males) met our inclusion/exclusion criteria. PAR, ICON, and ABO-OGS indices were recorded on pretreatment and post-treatment dental cast models to evaluate outcomes of orthodontic care. To assess distalization and predictability of distalization, superimposition of pretreatment and post-treatment lateral head films was completed on the Total Interactive Orthodontic Planning System (TIOPS, Denmark). Accuracy of mandibular first molar and second premolar positions was confirmed on occlusalgrams traced from pretreatment and post-treatment dental cast models.

Results: The majority of subjects treated with mandibular arch distalization using TSAD anchorage resulted in successful outcomes as defined by the PAR, ICON, and ABO-OGS indexes. The average treatment time was 28.3 months. The treatment in this subject population resulted in significant changes of the occlusal plane, overjet, maxillary incisor proclination, maxillary to mandibular molar and incisor angulation, nasolabial angle, and upper lip position. All mandibular dental movement was highly significant except for the horizontal and tipping of the mandibular incisors. On average, the mandibular molars were distalized bodily -1.95mm and tipped -6.05 degrees, and the second premolars were distalized -2.27mm and tipped -4.99 degrees. Seven of these subjects experienced greater then 2-mm of molar bodily distalization. It was found that in these seven subjects, distal movement of greater then 2-mm was significantly correlated with before treatment ANB, upper incisor proclination, and maxillary to mandibular incisal angulation.

Conclusion: In a mild Class III non-growing patient, distalization of the mandibular dentition using TSAD anchorage can predictably achieve a successful orthodontic outcome.

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INTRODUCTION

The correction of a Class III malocclusion in the non-growing patient is commonly treated with either camouflage extractions, surgery, or with severe compensatory proclination of the maxillary incisors and severe retroclination of the mandibular incisors. An alternative method of treatment that is rarely attempted is distalization of the mandibular dentition. Distalization of the mandibular molars has been recognized as one of the most difficult treatment objectives in clinical orthodontics especially when compared to distalization of the maxillary molars.[1] Due to the difficulty and unpredictability of this treatment modality, it is rarely attempted. There have been a variety of methods attempted in the distal movement of the mandibular molars such as a lip bumper,[2] a distal extension lingual arch,[3] or even using a multiloop edgewise archwire.[4] In most of these techniques there is mostly tipping of the mandibular molars rather than bodily translation, and treatment results rely heavily on patient compliance. However, presently, with the more common use of temporary skeletal anchorage devices (TSAD), distalization of the mandibular dentition can be achieved with less reciprocal side effects when compared to more traditional methods of mandibular dental distalization.[2-4] Utilizing TSAD's for mandibular molar distalization allows clinicians to correct anterior crossbites, mandibular incisor crowding, and mandibular asymmetries without the necessity of extracting teeth.[5]

The use of temporary skeletal anchorage devices developed in the 1990's allows orthodontists versatility in setting more stable anchorage rather than relying on conventional tooth-borne anchorage mechanics. The two types of TSAD's that have been developed are those that are able to osseointegrate with bone, and those that are mechanically retained within

bone.[6] TSAD's with the ability to osseointegrate are retromolar implants, palatal implants, and mini-implants. Those that are mechanically retentive are known as miniplates and miniscrews.[6] In current literature, there have been multiple case reports published where miniplates and miniscrews were used to achieve mandibular molar Distalization. [5, 7] Miniplates are made in various configurations and fabricated of titanium or titanium alloys. They are composed of three parts: head, arm, and body. The head portion is exposed intraorally, while the arm is partially covered by gingival mucosa.[6] The body of the miniplate is positioned against bone after a mucoperiosteal flap is elevated (Figure 1), and retained with two or three miniscrews fitted to the plate.[6, 8]

Figure 1: Mucoperiosteal flap for placement of miniplate. [8]

The body portion is classified into 4 shapes: T, Y, L, and I (which is also called straight).[6] The whole procedure is completed under local anesthetic and usually positioned in the retromolar pad area of the mandible (Figure 2). Although the use of miniplates for mandibular molar distalization can be achieved without patient compliance, the appropriate

evaluation of mandibular posterior arch space and appropriate distalization mechanics must be performed.

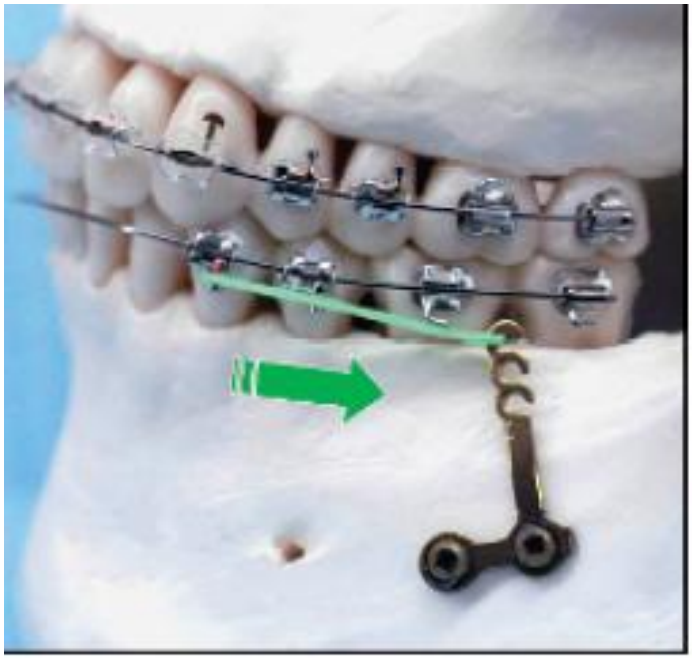

Figure 2: L type miniplate in retromolar pad. [8]

When deciding on mandibular Distalization, there are a few factors to consider: required space, hard tissue conditions, and soft tissue conditions.[9] If the "required space" needed to achieve the treatment objective is more than 3-mm of space per side, it is recommended to extract premolars for treatment efficiency.[9] When evaluating "hard tissue", there must be enough space for distalization, because there is a posterior anatomic limit beyond which orthodontic movement cannot be achieved. [9] In previous literature, the anterior border of the ramus measured along the occlusal plane was considered to be the posterior limit of the mandibular arch. However these studies were based on two-dimensional panoramic

radiographs or lateral cephalograms.[10-12] A recent investigation by Kim *et al.*, evaluated the posterior anatomic limit using three-dimensional computed tomography and concluded that the posterior limit in Cl I mesocephalic subjects with normal occlusion is the lingual cortex of the mandibular body. [13] It was recommended in this study to take a CBCT image for those patients in whom a large distalization movement is planned to be completed as an objective in treatment. Also, It might be advisable to extract mandibular second or third molars to achieve adequate space in the mandibular arch.[9] Lastly, "soft tissue" conditions need to be evaluated when deciding on mandibular distalization. Specifically, the distobuccal aspect of the mandibular second molar needs to be in attached gingiva following distalization.[9] Even if mandibular distalization can be achieved, it is important to assess whether treatment outcomes produce an orthodontically acceptable result.

There are multiple ways of assessing difficulty in pretreatment orthodontic cases and in assessing quality of treatment once treatment has been completed. It is difficult to standardize judgments because of the multifactorial nature of malocclusion, which includes a patient's expectations, psychological needs, and physical characteristics of occlusion.[14] The usefulness of occlusal indexes in auditing, research, decision making, and assessing pretreatment and posttreatment outcomes is well accepted internationally.[14] Some of the frequently used indexes are the peer assessment rating (PAR), the index of complexity, outcome, and need (ICON), and the American Board of Orthodontics objective grading system (ABO-OGS). The PAR can provide a summary score for occlusal anomalies and an estimate of how far a malocclusion deviates from normal alignment and occlusion.[15] It also has the ability to grade the improvement of a case. It was weighted to match the judgment of a panel of general dentists and British orthodontists on the deviation of a case from normal and has

been used to evaluate treatment standards.[15] Another index similar to PAR, but also evaluates visual need for orthodontic treatment is the ICON. The ICON addresses the issues of treatment need complexity, treatment improvement, and outcome based on international professional opinions, intended for use in the context of a specialist practice.[16] The ICON was developed in 9 countries by 97 orthodontists.[14] It has shown high validity, and several European studies have shown good reliability.[14] Among orthodontist in the United States, a board certified orthodontist uses the ABO-OGS to assess the difficulty of cases and the quality of outcome of treatment. In 1994, the American Board of Orthodontics began investigating methods of making the phase III examination more objective.[14] An objective method of evaluating dental casts and radiographs was eventually developed after a series of 4 field tests over 5 years.[14] In 1999, the ABO instituted the model and radiographic portions of the objective grading system to be officially used to grade portions of the candidates' clinical case reports.[14] All of these indexes, PAR, ICON, and ABO-OGS, rate pretreatment difficulty and outcomes of care by their own specific standards of evaluation. The major differences between these indexes are "improvement scores" are only generated from the PAR and ICON. The ICON is the only index that takes into consideration the "visual" appearance of a malocclusion, and the ABO-OGS is the only index that evaluates radiographic images before and after treatment.

Since current literature in the assessment of mandibular dental distalization using temporary skeletal anchorage devices is minimal and mostly consists of case reports. It is important to thoroughly evaluate this modality of treatment and decide if mandibular dental distalization can be a predictable treatment objective, and if the outcome is orthodontically acceptable. Therefore, the purpose of this investigation was to: 1) use the PAR, ICON, and

ABO-OGS indices to access the quality of outcome using TSADs to distalize the mandibular dentition in the class III non-growing patients; 2) to evaluate the dental movement of the mandibular first molars, second premolars, and incisors between subjects; and 3) to identify predictable characteristics in pretreatment subjects that resulted in greater dental movement. My hypothesis is distalization of the mandibular dentition using TSAD anchorage in a Class III non-growing patient will result in an acceptable orthodontic outcome.

MATERIALS AND METHODS

Sample

This was a retrospective clinical study that evaluated the outcomes of orthodontic treatment of patients treated with mandibular dental distalization using TAD anchorage. Records normally taken before and after treatment were evaluated. Records consisted of initial (T1) lateral cephalogram, panoramic radiograph, pre-treatment dental models and post-treatment (T2) lateral cephalogram, panoramic radiograph, and post-treatment dental models. The subjects received treatment in the National Taiwan University, Orthodontic and Dentofacial Orthopedic Oral Biology Clinic in Taiwan. Subjects were selected based on completion of orthodontic treatment in the past five years in which TAD anchored mandibular dental distalization was used. Patients seen at NTU signed consent forms for their clinical data to be evaluated after removal of identifying information and IBR approval was obtained. CHR approval was also obtained at UCSF reference # 13-11083.

There were 27 total subjects selected, but only 20 subjects met the inclusion and exclusion criteria. The inclusion criteria consisted of: 1) Class III molar relationship (unilateral or bilateral) of ½ cusp or 1/1 cusp; 2) retreatment of previous failed orthodontic treatment that

may have initially been treated with premolar extraction; 3) post pubertal patients with little or no growth expected at the start of orthodontic treatment; 4) full treatment completed. The exclusion criteria consisted of: 1) incomplete records; 2) premolar extractions for current treatment; 3) growth expected during treatment; and 4) orthognathic surgery.

The 20 subjects that met the latter criteria were an average age of 23.5y ± 5.9 and consisted of 10 males and 10 females. The average treatment time for these subjects was 28.3-mo ± 6.8. The subjects were treated with either miniscrews or miniplates as a form of skeletal anchorage that aided in mandibular dental distalization. The sample distribution can be viewed in Table 1.

Table 1 Sample distribution

	N	*Age at T1 (year)*		*Treatment time (month)*	
		Mean	*SD*	*Mean*	*SD*
Total	20	23.5	5.9	28.3	6.8
Male	10	21.5	2.4	31.2	5.2
Female	10	25.2	7.4	25.4	7.3

Orthodontic Outcome Assessment

Three different validated indexes were used in order to evaluate the outcome of orthodontic treatment using this modality of treatment. These indexes were the Peer Assessment Rating Index (PAR), the Index of Complexity, Outcome and Need (ICON), and the American Board of Orthodontics Objective Grading System (ABO-OGS). Each of these indexes were evaluated on pre/post treatment dental models, pre/post treatment clinical photos (only for

ICON), and pre/post treatment lateral cephalograms and panoramic radiographs (only for ABO-OGS). The PAR index grades pre/post treatment casts in the components shown in Table 2. A 70% change from pre-treatment score signifies a greatly improved case.

Table 2:

Components of the PAR Index.

1.	Upper right segment
2.	Upper anterior segment
3.	Upper left segment
4.	Lower right segment
5.	Lower anterior segment
6.	Lower left segment
7.	Right buccal occlusion
8.	Overjet
9.	Overbite
10.	Centreline
11.	Left buccal occlusion

The ICON index evaluates the components shown in Table 3 and has a weighted score for each component.

Table 3: The ICON Index Components

	Components:	Score						Weight
		0	1	2	3	4	5	
1	Aesthetic assessment	Score 1 to 10						7
2$	Upper arch crowding	< 2mm	2.1-5mm	5.1-9mm	9.1-13mm	13.1-17mm	> 17mm	5
	Upper arch spacing	< 2mm	2.1-5mm	5.1-9mm	> 9mm		Impacted teeth	5
3	Crossbite	No crossbite	Crossbite present					5
4*	Incisor open bite	Edge to edge	< 1mm	1.1-2mm	2.1-4mm	> 4mm		4
	Incisor overbite	<1/3 lower incisor coverage	1/3 to 2/3 coverage	2/3 up to fully covered	Fully covered			4
5^	Buccal segment A-P	Cusp to embrasure only, Class I,II or III	Any cusp relation up to but not including cusp to cusp	Cusp to cusp				3

$ The difference between the sum of the mesio-distal tooth diameters and the available arch circumference in the upper arch is recorded on a 5 point score. Impacted teeth (score 5) must be un-erupted and either ectopic or have less than 4 mm of space between adjacent permanent teeth. Retained deciduous teeth (without permanent successor), erupted supernumerary teeth or lost teeth due to trauma are counted as space, unless they are to be maintained and obviate the need for prosthetic replacement or space is maintained for a prosthetic replacement (i.e. tooth lost in trauma).
* If both anterior open bite and deep bite are present only the highest score is counted.
^ Quality of buccal segment interdigitation, not the Angle Classification, is measured on both sides then added together

The ABO-OGS evaluates pre-treatment dental models and radiographs to calculate a "Discrepancy Index" score (DI score; Table 4), and post-treatment dental models and radiographs to generate their "Cast and Radiograph" evaluation (CR score) shown in Figure 3 and Table 5. . Each of these indexes was completed on all subjects by one orthodontist and then repeated again on all subjects two weeks later by the same orthodontist.

Table 4: ABO Discrepancy Index (DI)

EXAM YEAR _____ **ABO DISCREPANCY INDEX**

ABO ID # _____ **CASE# _____** **PATIENT _____**

TOTAL D.I. SCORE ☐

For mm measures, round up to the next full mm.
Examiners will verify measurements in each category.

OVERJET

≥ 0 to < 1 mm (edge-to-edge)	= 1 pt
≥ 1 to ≤ 3 mm	= 0 pts
> 3 to ≤ 5 mm	= 2 pts
> 5 to ≤ 7 mm	= 3 pts
> 7 to ≤ 9 mm	= 4 pts
> 9 mm	= 5 pts
Negative Overjet (x-bite): 1 pt per mm per tooth	= ___pts
Total	☐

OVERBITE

> 1 to ≤ 3 mm	= 0 pts
> 3 to ≤ 5 mm	= 2 pts
> 5 to ≤ 7 mm	= 3 pts
Impinging (100%)	= 5 pts
Total	☐

ANTERIOR OPEN BITE

0 mm (edge-to-edge), 1 pt per tooth	=_____pts
then 1 pt per mm per tooth	=_____pts
Total	☐

LATERAL OPEN BITE

≥ 0.5 mm, 2 pts per mm per tooth

Total ☐

CROWDING (only one arch)

≥ 0 to ≤1 mm	= 0 pts
> 1 to ≤ 3 mm	= 1 pts
> 3 to ≤ 5 mm	= 2 pts
> 5 to ≤ 7 mm	= 4 pts
> 7 mm	= 7 pts
Total	☐

OCCLUSAL RELATIONSHIP

Class I to End On	= 0 pts	
End-to-End Class II or III	= 2 pts per side	____pts
Full Class II or III	= 4 pts per side	____pts
Beyond Class II or III	= 1 pt per mm additional	____pts
Total		☐

LINGUAL POSTERIOR X-BITE

> 0 mm, 1 pt per tooth Total ☐

BUCCAL POSTERIOR X-BITE

> 0 mm, 2 pts per tooth Total ☐

CEPHALOMETRICS (See Instructions)

ANB ≥ 6° or ≤ -2°	@4pts	= ___
Each full degree > 6°	___x 1 pt	= ___
Each full degree < -2°	___x 1 pt	= ___
SN-MP		
≥ 38°	@2pts	= ___
Each full degree > 38°	___x 2 pts	= ___
≤ 26°	@1pt	= ___
Each full degree < 26°	___x 1 pt	= ___
$\bar{1}$ to MP ≥ 99°	@1pt	= ___
Each full degree > 99°	___x 1 pt	= ___
Total		☐

OTHER (See Instructions)

Supernumerary teeth	___x 1 pt	= ___
Ankylosis of permanent teeth	___x 2 pts	= ___
Anomalous morphology	___x 2 pts	= ___
Impaction (except 3rd molars)	___x 2 pts	= ___
Midline discrepancy (≥3 mm)	@ 2 pts	= ___
Missing teeth (except 3rd molars)	___x 1 pt	= ___
Missing teeth, congenital	___x 2 pts	= ___
Spacing (4 or more, per arch)	___x 2 pts	= ___
Spacing (mx cent diastema ≥ 2 mm)	@ 2 pts	= ___
Tooth transposition	___x 2 pts	= ___
Skeletal asymmetry(nonsurgical tx)	@ 3 pts	= ___
Addl. treatment complexities	___x 2 pts	= ___

Identify:

Total Other ☐

30130315

Table 5: ABO Cast and Radiograph Evaluation (CR)

Reference - ABO Cast/Radiograph Evaluation

See Grading System for Casts-Radiographs for entire discussion

ALIGNMENT/ROTATIONS

0.5 – 1 mm = 1 for each tooth
> 1 mm = 2 for each tooth

OCCLUSAL CONTACTS

0 mm = satisfactory
≤ 1 mm = 1 (for each posterior
> 1 mm = 2 tooth out of contact)

** Do **not** score diminutive distolingual cusps of the maxillary 1st and 2nd molars, nor lingual cusps of the mandibular first premolars. **Maximum of 2 points per tooth**.

MARGINAL RIDGES

0.5 - 1 mm = 1 (for each interproximal contact
> 1 mm = 2 between posterior teeth)

** Do **not** include the canine-premolar contact.
Do **not** include the distal of lower 1st premolar.

OCCLUSAL RELATIONSHIP

< 1 mm = satisfactory
1 - 2 mm = 1 (for each maxillary **tooth** from the
> 2 mm = 2 the canines to the 2nd molars)

BUCCOLINGUAL INCLINATION

0 - 1 mm = satisfactory
1.1 - 2 mm = 1 (for each posterior tooth)
> 2 mm = 2

** Do **not** score the mandibular 1st premolars nor the distal cusps of the second molars.

INTERPROXIMAL CONTACTS

0.6 - 1 mm = 1 (for each interproximal
> 1 mm = 2 **contact)**

OVERJET

Anterior teeth must be contacting.

0 mm = satisfactory
≤ 1 mm = 1 (for each maxillary
> 1 mm = 2 tooth)

Transverse posterior teeth:
Mandibular buccal cusps are measured to the central fossa of the maxillary teeth.

ROOT ANGULATION

Parallel = 0
Not parallel = 1
Root contacting
adjacent root = 2 (for each **occurrence**)

Do **not** score the maxillary and mandibular canines.

NOTE: Gauge Width is 0.5 mm; Gauge Height is 1 mm
Third molars are not scored unless they substitute for the second molars.
No tooth is scored more than two points per individual parameter.

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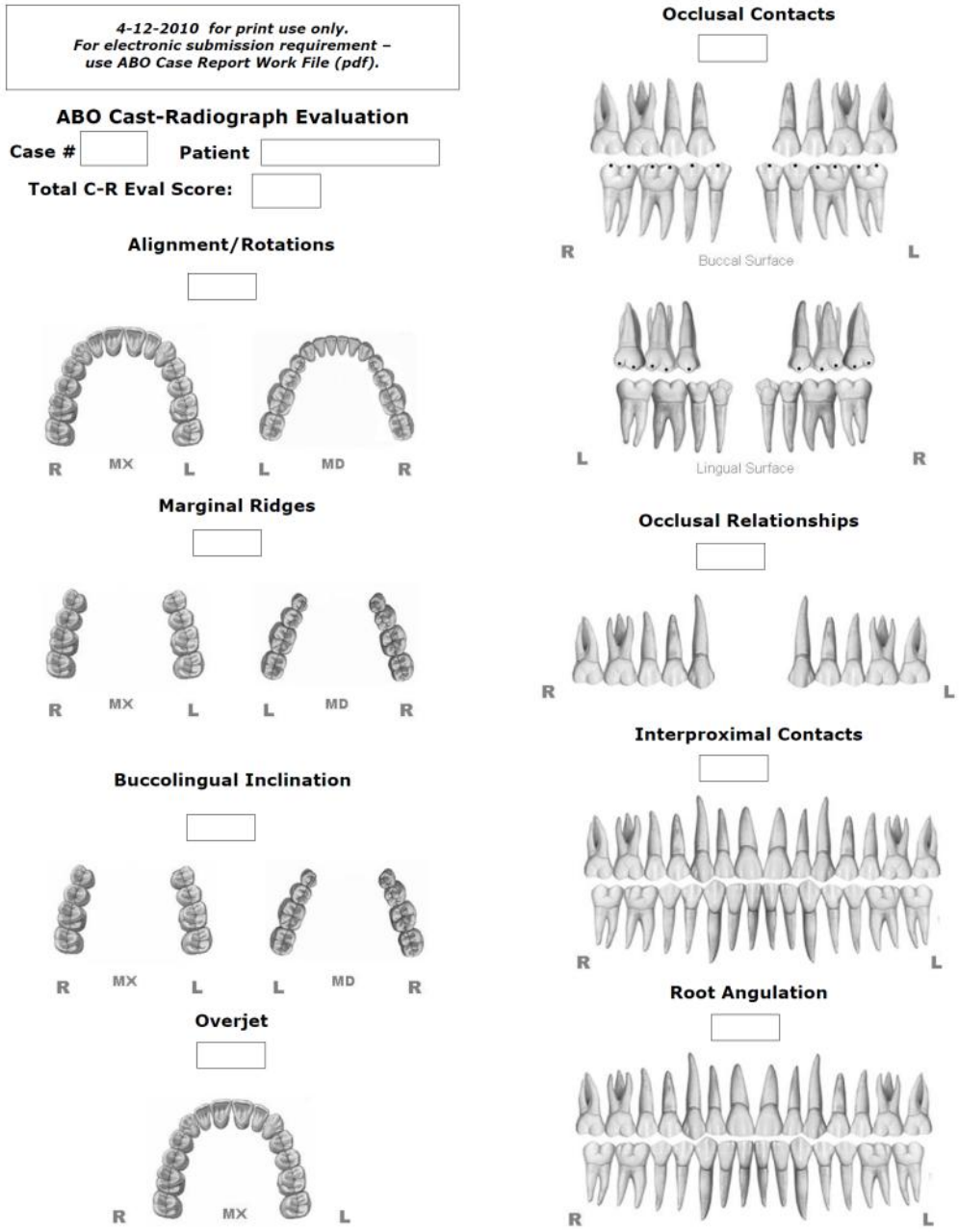
Figure 3: The ABO Cast and Radiograph Evaluation



Evaluation of Mandibular Dental Distalization

Lateral head films taken before (T1) and after treatment (T2) were entered digitally into the Total Interactive Orthodontic Planning System (TIOPS4; Copenhagen, Denmark). The lateral head films were then digitized and superimposed on the TIOPS. Occlusograms were also traced using this program on all before and after treatment dental models. The distance from the facial surface of the mandibular incisors to the mesial portion of the second premolar and first molar was recorded from the occlusograms. If the case were a unilateral distalization treatment, only the measurement of the distalized side was used. If there was bilateral distalization of the second premolar and first molar, a point median to the mesial portion of these contralateral teeth was recorded. These measured distances were then used to accurately position the second premolar and first molar on the traced before (T1) and after treatment (T2) lateral head films. All occlusograms and lateral cephalograms were digitized by one investigator and checked by another examiner. The second examiner checked for accuracy of landmark location and superimposition accuracy. Any disparities between landmarks or superimposition were resolved by mutual agreement. The cephalometric landmarks evaluated are described in Table 6. The lateral head film at T2 was superimposed onto the lateral head film at T1 on the stable structures of the ethmoid bone and the anterior portion of sella turcica along the cranial base. Individual superimposition of the maxilla and mandible was also completed to allow for accurate representation of dental only movements. The maxillary superimposition was made on the anterior-superior surface of the zygomatic process of the maxilla and the mandibular superimposition was made along the internal border of the mandibular symphysis as well as the internal cortication of the inferior alveolar canal.

Table 6: Measurements used with the TIOPS

Measurement	*Description*
SNA (°)	Angle between Sella-Nasion and Nasion-A point
SNB (°)	Angle between Sella-Nasion and Nasion-B point
SNPog (°)	Angle between Sella-Nasion and Nasion-Pogonion
ANB (°)	Angle between A point-Nasion and Nasion- B point
ANPog (°)	Angle between A point-Nasion and Nasion- Pogonion
PP to ML (°)	Angle between palatal plane and mandibular plane
ML to L1 (°)	Angle between mandibular plane and axis of lower incisor
PP to U1 (°)	Angle between palatal plane and the upper incisor
PP to Ops (°)	Angle between palatal plane and upper occlusal plane
OB (mm)	Vertical distance between upper and lower incisor tips
OJ (mm)	Horizontal distance between upper and lower incisor tips
Mols/Moli (°)	Angle between maxillary and mandibular molars
Nst-sn-ls (°)	Nasolabial angle
Is-NCL (mm)	Upper lip position
li-NCL (mm)	Lower lip position
Ils/iLi (°)	Angle between upper and lower incisors

Mandibular Specific Measurements

Measurement	*Description*
L6H (mm)	Net horizontal movement of the lower fist molar along the mean occlusal plane

	(+) Mesial movement (-) Distal movement
L5H (mm)	Net horizontal movement of the lower second premolar along the mean occlusal plane
	(+) Mesial movement (-) Distal movement
L1H (mm)	Net horizontal movement of the lower incisor along the mean occlusal plane
	(+) Mesial movement (-) Distal movement
L6V (mm)	Net vertical movement of the lower first molar in relation to the mean occlusal plane
	(-) Intrusion (+) Extrusion
L5V (mm)	Net vertical movement of the lower second premolar in relation to the mean occlusal plane
	(-) Intrusion (+) Extrusion
L1V (mm)	Net vertical movement of the lower incisor in relation to the mean occlusal plane
	(-) Intrusion (+) Extrusion
L6 Inc (°)	Net angular change of the lower first molar
	(+) Mesial tipping (-) Distal tipping
L5 Inc (°)	Net angular change of the lower second premolar
	(+) Mesial tipping (-) Distal tipping
L1 Inc (°)	Net angular change of the lower incisor
	(+) Mesial tipping (-) Distal tipping

Statistical Analysis

All data was analyzed by a statistician in the Department of Neurology at the University of California at San Francisco. Descriptive statistics including means and standard deviations

were calculated for all before and after treatment outcome indices and for all cephalometric measurements at T1 and T2 timepoints using paired t-tests. Paired t-test was also done for dental movement outcomes. Additionally, male vs. female T1 cephalometric measurements, T2 cephalometric measurements, and mandibular dental movements after treatment were assessed for statistical significant differences. Predictor correlation analysis was also completed on T1 cephalometric measurements and dental movements for all subjects. Significant findings from this correlation, then underwent a regressions analysis that was adjusted for gender and age. All patients who had greater than 2-mm of molar distalization underwent another paired t-test comparing before cephalometrics for significant differences. The significant differences then underwent logistic regression analysis to interpret the relationship of that measurement and the greater than 2-mm of molar distal movement.

RESULTS

Orthodontic Outcome Assessment

The PAR assessment showed an average score of 36.68 ± 6.52 for the entire sample at T1 recorded from pre-treatment models (Figure 4-1). The average PAR value at the end of treatment was 2.35 ± 1.58 (Figure 4-2), which resulted in a score change of 33.75 ± 7.81 (Figure 4-3). These scores changed on average by 92%. The PAR index states that when a score changes by 70%, it signifies a greatly improved case.

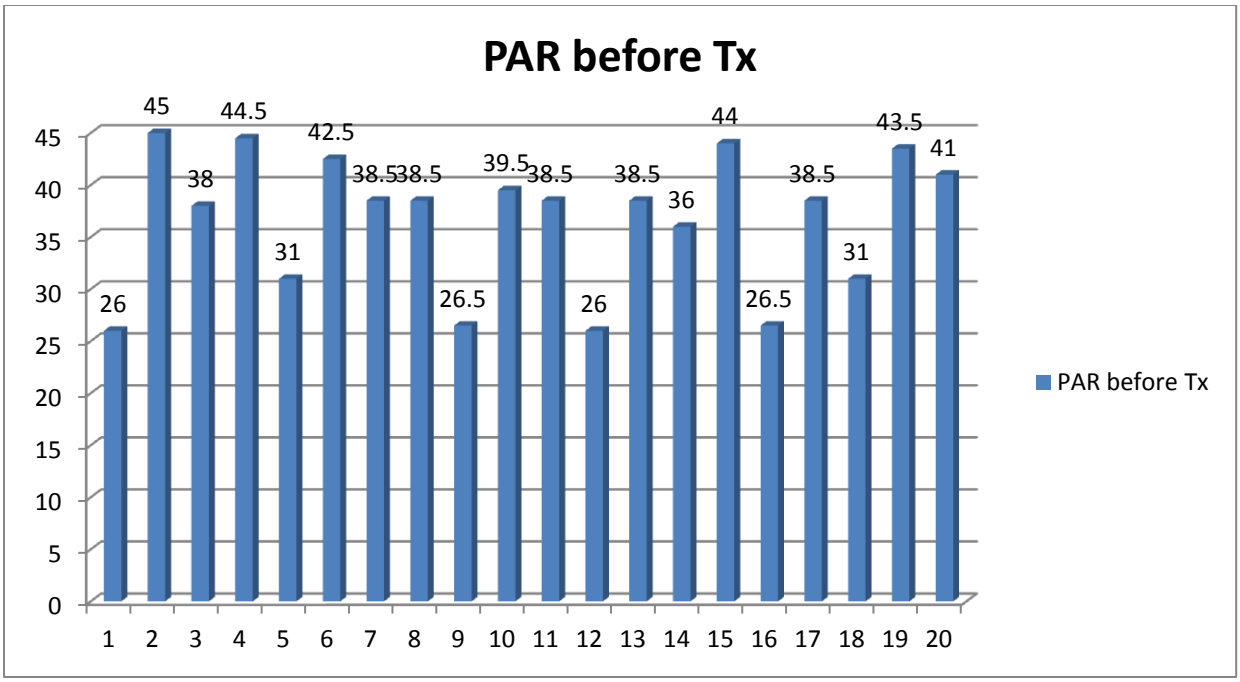


Figure 4- 1: PAR score at T1.

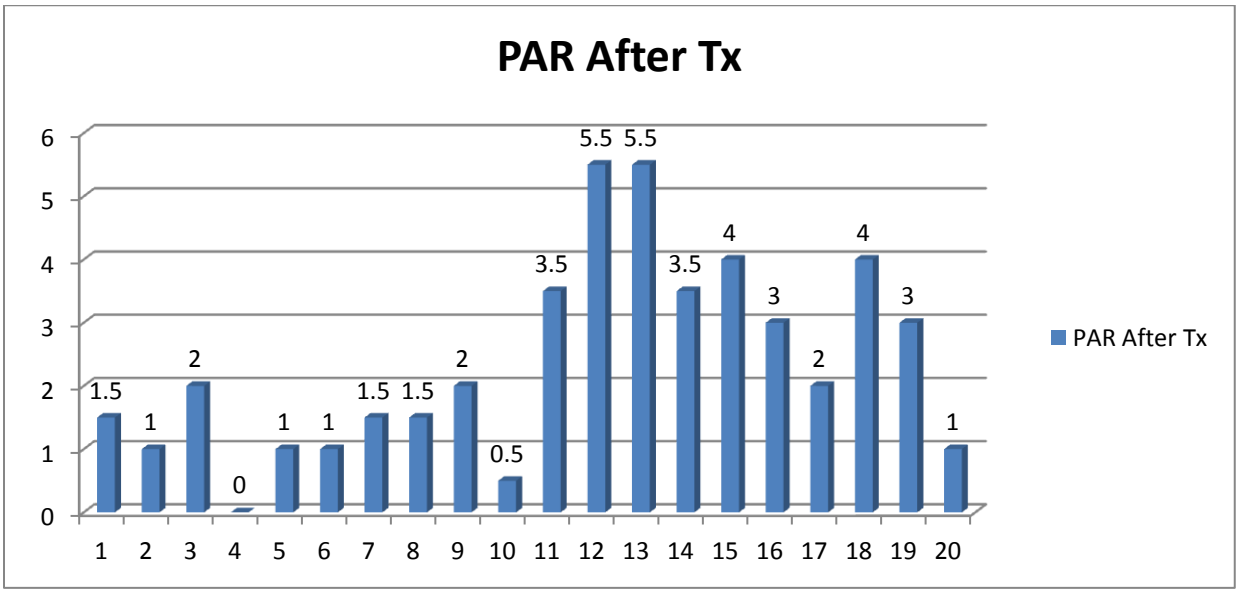


Figure 4- 2: PAR score at T2.

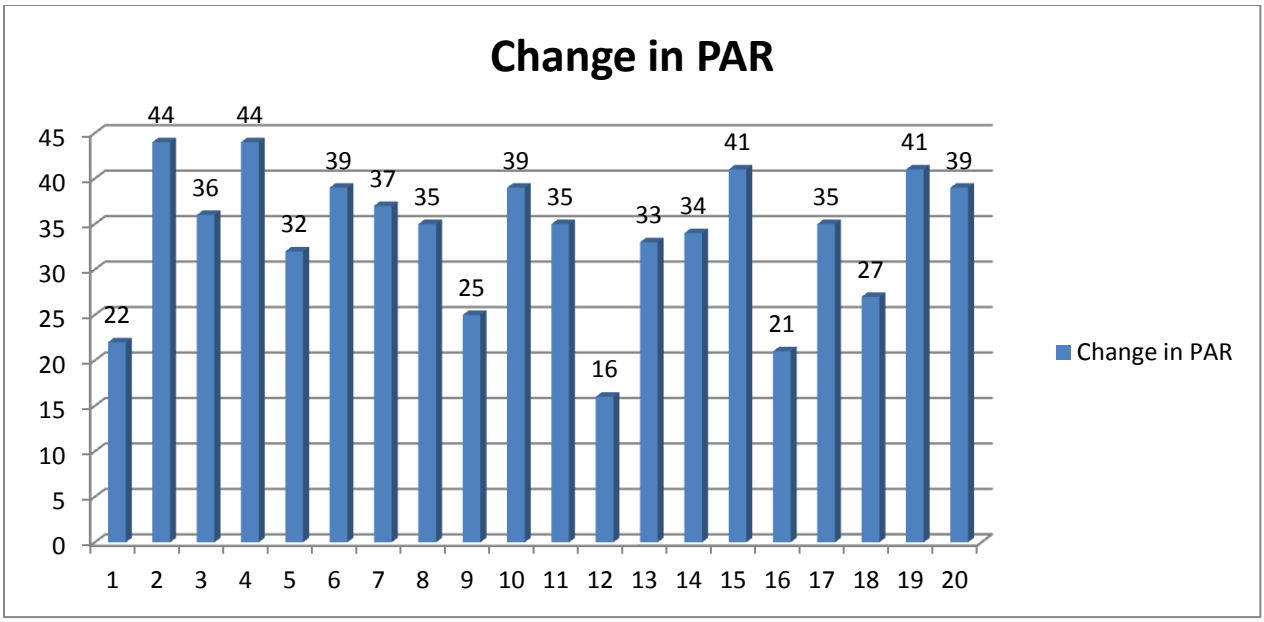


Figure 4- 3: Change in PAR score.

The ICON revealed an average score of 60.7 ± 18.70 at T1 (Figure 5-1). The average after treatment was completed was 16 ± 4.06 (Figure 5-2). The ICON index does have an improvement rating equation that classifies how much each case has changed. Figure 5-3 displays the improvement rating of each patient and how much of an improvement that is correlated with that score. The average improvement rating for the whole sample was 8.67 ± 25.76. The improvement rating showed that all cases but one were "substantially" to "greatly" improved. The one case that was not in this group was "moderately" improved.

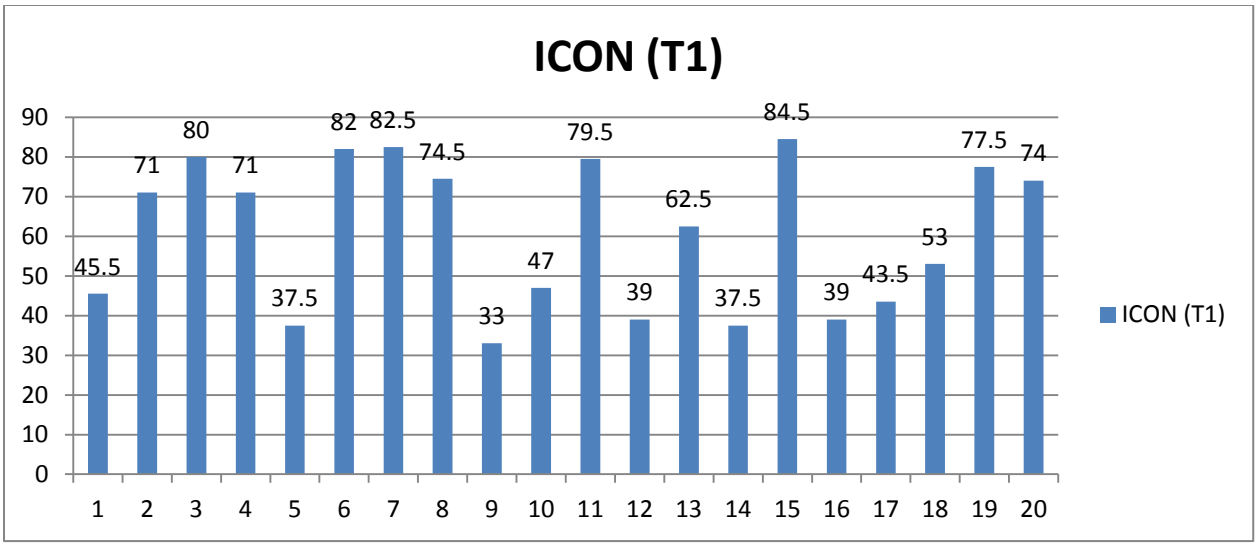


Figure 5- 1: ICON score at T1.

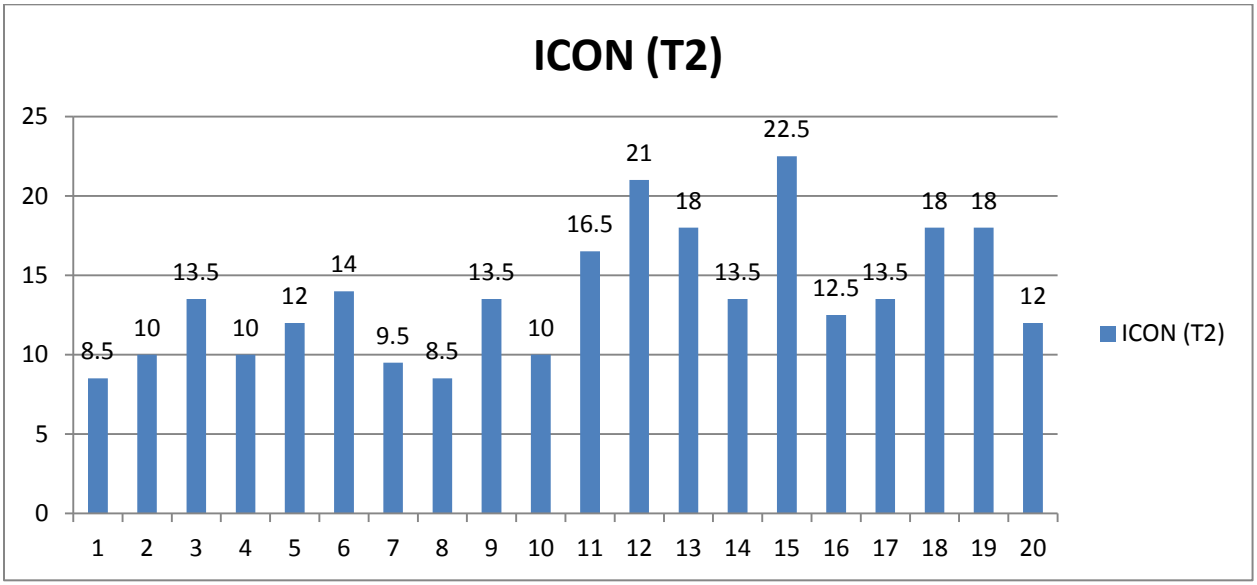


Figure 5- 2: ICON score at T2.

Improvement Grade	Score Range
Greatly improved	> -1
Substantially improved	-25 to -1
Moderately improved	-53 to -26
Minimally improved	-85 to -54
Not improved or worse	< -85

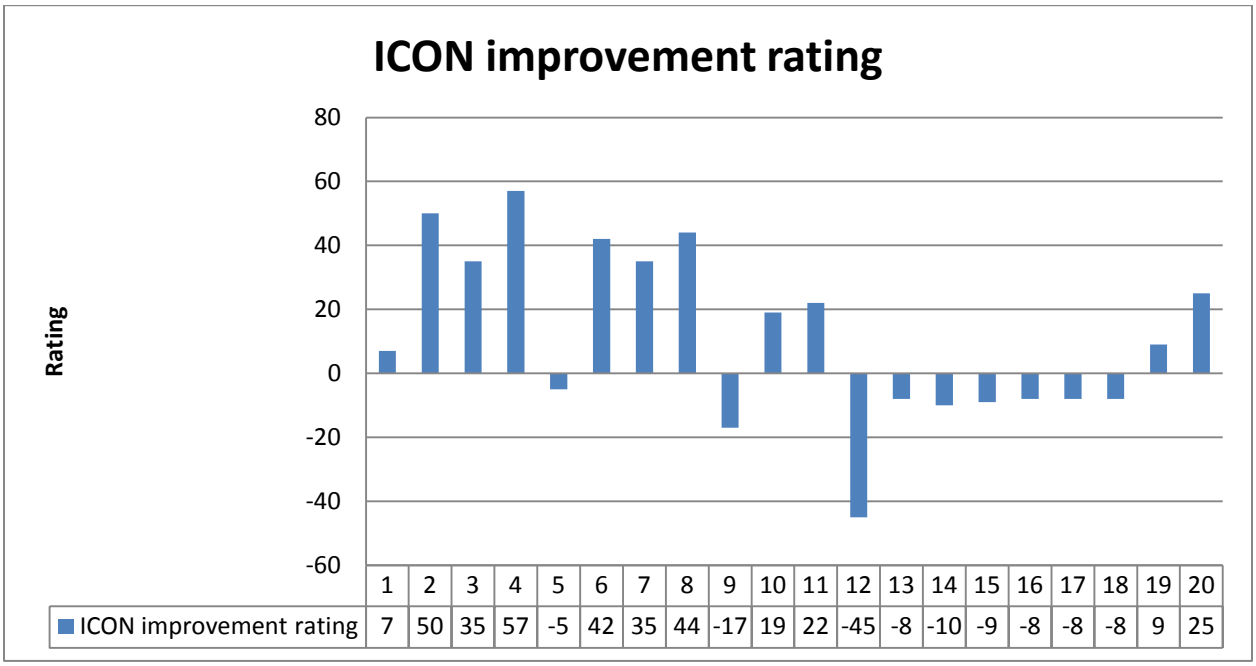


Figure 5- 3: ICON improvement scores and grade.

The last index used to assess the orthodontic treatment outcome was the ABO-OGS. The discrepancy index (DI) score for all the subjects at T1 was 19.5 ± 8.4 (Figure 6-1). A DI score greater than 10 allows that case to be considered for membership into the American Board of Orthodontics group. The final model evaluation by the ABO-OGS is named the Cast/Radiograph (CR) evaluation. The CR score on average at T2 was 20 ± 7.6. Figure 6-2 shows the individual CR scores for each subject.

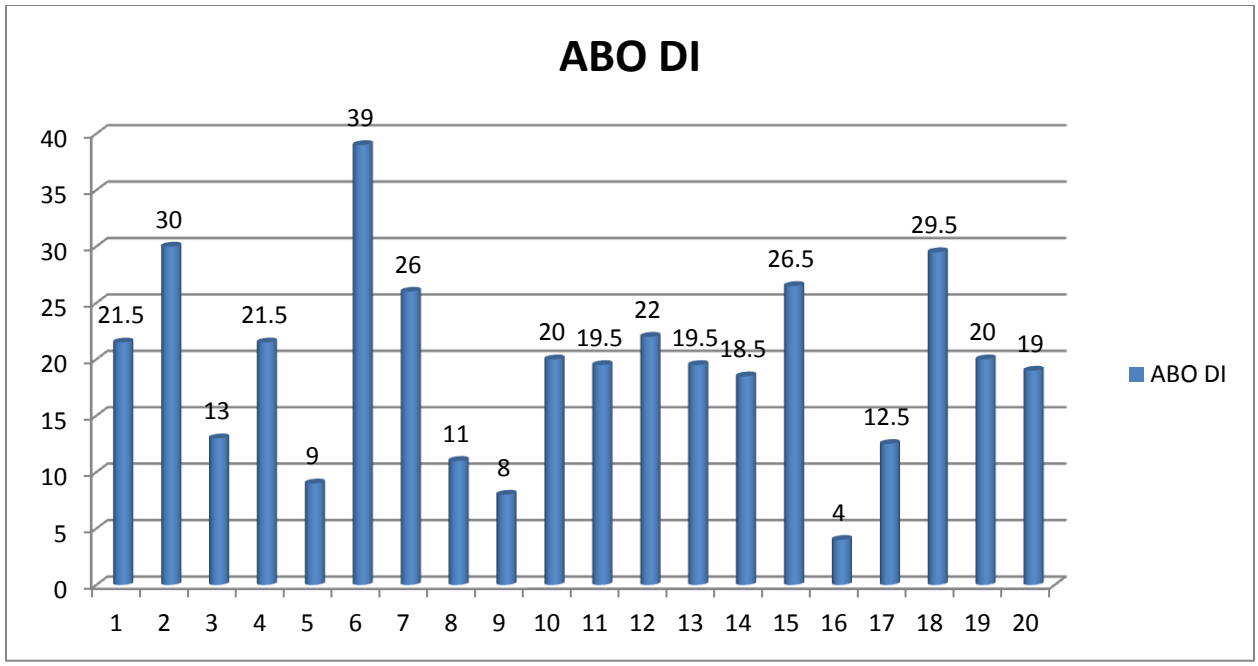


Figure 6- 1: Discrepancy Index score at T1

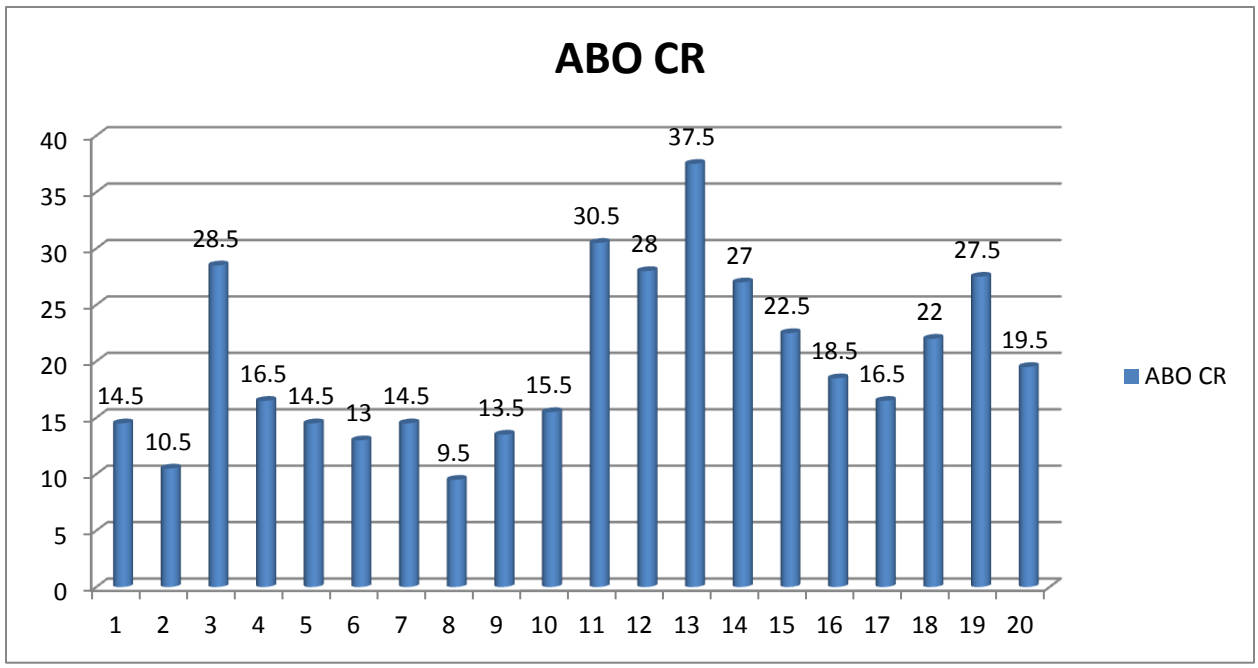


Figure 6- 2: Cast/Radiograph score at T2

Evaluation of Mandibular Dental Distalization

Gender Differences

The initial evaluation preformed was to compare gender within the subject pool to evaluate differences in ceph measurements at T1, T2, and dental movements. The only difference between male and female for the before ceph measurements was in mols/moli (female=166.3 [sd=3.53]; male=161.8 [sd=2.32], p=0.003). The female subjects had significantly more upright molar angulation between their maxillary and mandibular molars at T1.(Table 7-1). There were no significant differences found in the ceph measurements neither at T2 nor for any of the dental movements (Table 7-2; 7-3).

Table 7-1: MEASUREMENTS BETWEEN MALE AND FEMALE at T1

(p-value from unpaired t-test)	
Ceph at T1	
SNA	0.22
SNPog	0.999
SNB	0.62
ANPog	0.19
ANB	0.44
PP to Ops	0.94
PP to ML	0.91
overjet	0.93
overbite	0.67
PP to U1	0.59
ML to L1	0.31
ils_lli	0.09
Mols/Moli	0.003
nst-sn-ls	0.55
ls-NCL	0.68
li-NCL	0.95

Table 7-2: MEASUREMENTS BETWEEN MALE AND FEMALE at T2

(p-value from unpaired t-test)	
Ceph at T2	
SNA	0.50
SNPog	0.97
SNB	0.78
ANPog	0.42
ANB	0.69
PP to Ops	0.72
PP to ML	0.97
overjet	0.51
overbite	0.91
PP to U1	0.99
ML to L1	0.49
ils_lli	0.14
Mols/Moli	0.74
nst-sn-ls	0.23
ls-NCL	0.61
li-NCL	0.17

Table 7-3: P-value for gender differences in tooth movements.

(p-value from unpaired t-test)	
Tooth movements	
L1H	0.95
L1V	0.13
L1 Inc	0.87
L5H	0.79
L5V	0.09
L5 Inc	0.97
L6H	0.68
L6V	0.13
L6 Inc	0.68

Overall Sample

The mean ceph values at T1 and T2, as well as the mean dental movements can be viewed in Table 8-1, Table 8-2, and Table 8-3. On average, all the subjects started treatment with an edge to edge incisor relationship and a mild Cl III molar relationship. In Figure 7-1, it displays a mean tracing for all the subjects at T1. At T2, all the subjects finished in a Cl I molar relationship with normal overjet and overbite (Figure 7-2).

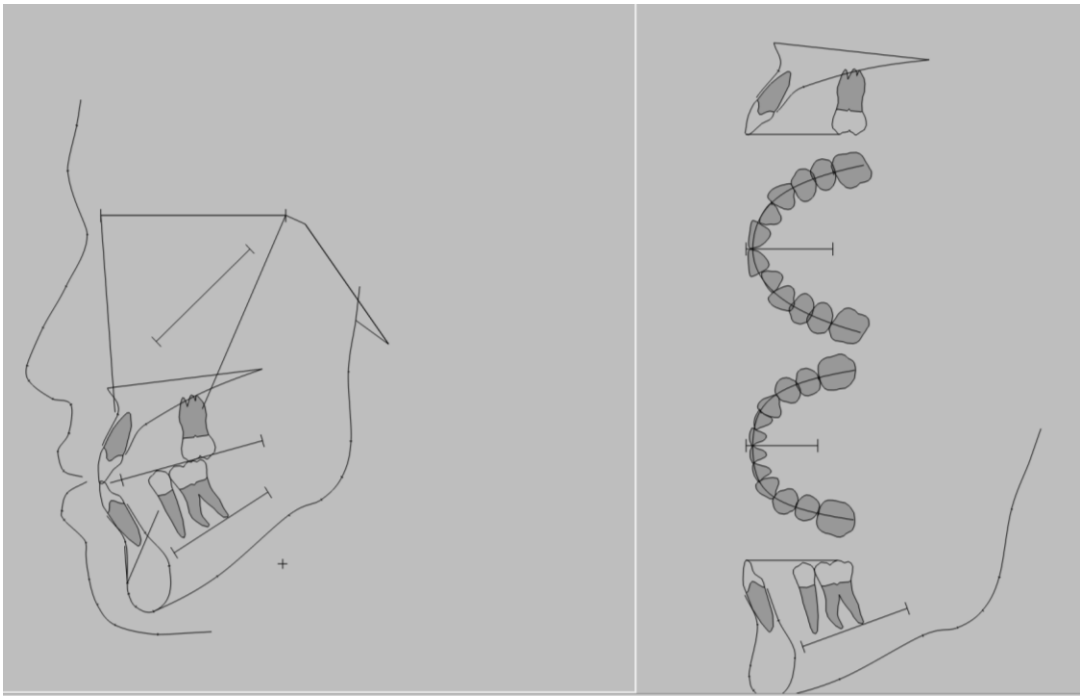


Figure 7- 1: Mean tracing for all subjects at T1

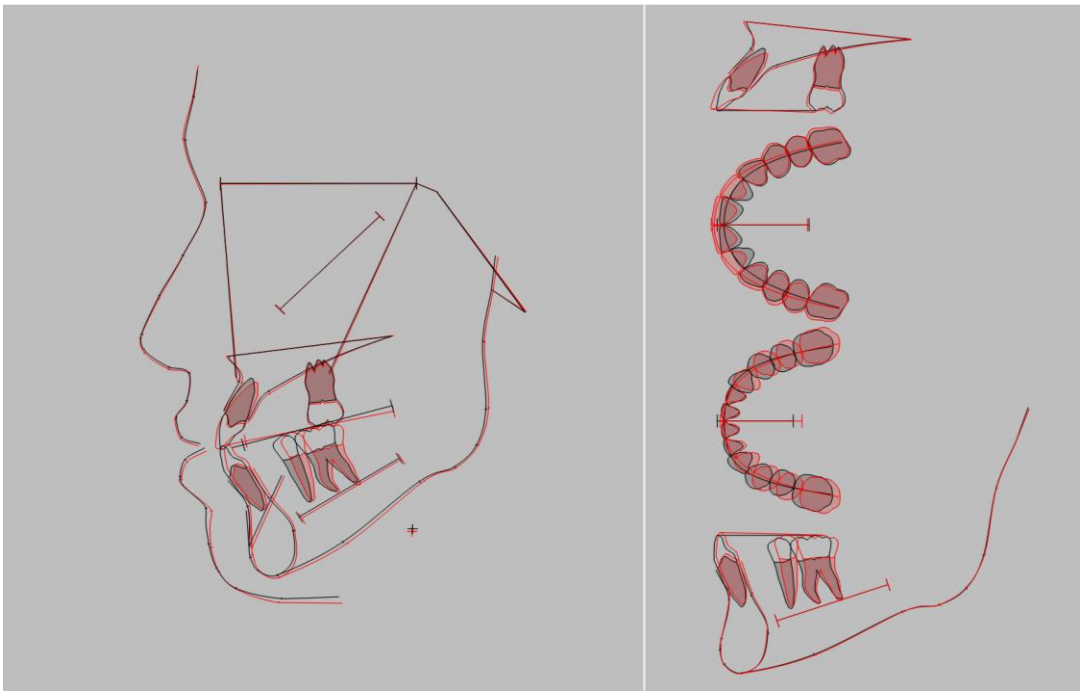


Figure 7- 2: Mean tracing before and after treatment for all 20 subjects

The next evaluation looked at the entire subject population as a whole and evaluated significant changes in ceph measurements from T1 to T2 and significant changes in tooth movement. The treatment in this subject population resulted in significant changes of the occlusal plane, overjet, maxillary incisor proclination, maxillary to mandibular molar and incisor angulation, nasolabial angle, and upper lip position (Table 8-5). All mandibular dental movements were highly significant except for the horizontal and inclination of the mandibular incisors. On average, the mandibular molars were distalized bodily -1.95-mm and tipped -6.05-degrees and the second premolars were distalized -2.27-mm and tipped -4.99-degrees (Table 8-3). In order to evaluate predictability of tooth movement, a regression analysis and Spearman correlation coefficient was performed on ceph measurements at T1 (Table 8-4). Significant correlations were found for SNPog and L1 vertical and L5 vertical movement, and also for

ANPog and L5 vertical movement. A significant correlation was also found for PP to U1 and the horizontal movement of L5 and L6. Another correlation was found for the nasolabial angle and the vertical movement of the L6. There was a significant correlations found for maxillary to mandibular molar angulation but will be disregarded due to this measurement being significantly different in the entire subject pool at the start of treatment.

Table 8- 1: Average Ceph values at T1

Ceph Landmark	Value
SNA	82.38638543
SNPog	83.36114034
SNB	83.15028616
ANPog	-0.9747549
ANB	-0.76390073
PP to Ops	17.62257217
PP to ML	34.64987558
overjet	-0.18592146
overbite	0.80050193
PP to U1	120.1656295
ML to L1	89.10340468
ils_lli	125.5760942
Mols/Moli	164.0569629
nst-sn-ls	90.25538495
ls-NCL	-2.71576474
li-NCL	1.677157724

Table 8- 2: Average Ceph vales at T2

Ceph Landmark	Value
SNA	81.77864025
SNPog	83.21624001
SNB	83.01820273
ANPog	-1.437599767
ANB	-1.239562487
PP to Ops	14.13290321
PP to ML	34.76973155
overjet	2.415231652
overbite	0.749257578
PP to U1	127.9130452
ML to L1	87.42761371
ils_lli	119.2636537
Mols/Moli	168.7343072
nst-sn-ls	85.56585686
ls-NCL	-2.178221902
li-NCL	1.720748255

Table 8- 3: Average tooth movement and P-value.

Mandibular Tooth	Movement	P-Value
L1H mm	-0.781806391	.07
L1V mm	0.864206727	.02
L1 Inc	-1.501706606	.27
L5H mm	-2.272047407	<.0001
L5V mm	0.978719765	.01
L5 Inc	-4.992067662	.0001
L6H mm	-1.954973515	.0004
L6V mm	0.954255916	.0004
L6 Inc	-6.058510691	<.0001

Table 8- 4: Correlation for Ceph measurements at T1 and Tooth Movement

CORRE-LATIONS [p-	SNPog	SNB	ANPog	ANB	PP to OP	OJ	OB	PP to U1	ils_lli	mols_moli1	nstsnls1

value]*												
TOOTH MOVEMENTS	L1 H	0.96	0.74	0.51	0.27	0.37	0.18	0.60	0.27	r=0.41 p=0.07	0.67	0.56
	L1 V	r=0.45 p=0.04	0.12	0.25	0.45	0.87	0.77	r=(0.42) p=0.07	0.65	0.53	r=(0.54) p=0.01	0.69
	L1 Inc	0.25	0.23	0.40	0.35	0.80	0.39	r=0.39 p=0.09	0.23	r=0.39 p=0.09	0.48	0.77
	L5 H	0.19	r=(0.39) p=0.08	0.19	r=0.43 p=0.06	0.96	0.58	0.58	r=(0.47) p=0.04	0.17	0.38	0.60
	L5 V	r = 0.45 p = 0.04	r=0.40 p=0.08	r=(0.46) p=0.04	r=(0.42) p=0.06	0.58	r=(0.42) p=0.07	0.18	0.78	0.50	r=(0.42) p=0.07	0.11
	L5 Inc	0.46	0.43	0.81	0.76	r=(0.40) p=0.08	0.79	0.23	0.92	0.80	r=0.40 p=0.08	0.63
	L6 H	0.40	0.17	0.28	r=0.40 p=0.08	0.72	0.55	0.71	r=(0.46) p=0.04	r=0.38 p=0.10	0.62	0.44
	L6 V	r=(0.20) p=0.09	0.17	r=(0.43) p=0.06	0.11	0.45	r=(0.37) p=0.10	0.27	0.80	0.83	r=(0.55) p=0.01	r=(0.51) p=0.02
	L6 Inc	0.39	0.31	0.70	0.57	0.89	0.62	0.70	0.90	0.96	r=0.37 p=0.10	0.53

* rho is only given if correlation is significant

Table 8- 5: Change in Ceph Values from T1 to T2

Change in Ceph Measurements		
Measurement	**Value**	**P-value**
SNA	(0.58)	0.22
SNPog	(0.13)	0.60
SNB	(0.13)	0.61
ANPog	(0.45)	0.30
ANB	(0.45)	0.29
PP to Ops	(3.25)	0.0001
PP to ML	0.04	0.87
overjet	2.57	<0.0001
overbite	(0.001)	0.997
PP to U1	7.77	<0.0001
ML to L1	(1.64)	0.24
ils_lli	(6.26)	0.02
Mols/Moli	4.68	0.0004
nst-sn-ls	(4.94)	0.002
ls-NCL	0.49	0.02
li-NCL	0.04	0.89

Greater than 2-mm of Molar Distal Movement

It was noted that seven subjects experienced more than 2-mm of bodily mandibular molar distalization. These subjects experienced an average -4.23 ± 1.49-mm of distalization. A paired t-test was done to compare the T1 values of these seven patients to the rest of the subjects. Significant differences were found in initial ANB, upper incisor proclination, and maxillary to mandibular incisor angulation (Table 8-6). Logistic regression was then completed on each of these three landmarks to evaluate how the odds of achieving 2-mm of molar distalization is associated with these values (Table 8-7). The odds ratio (OR) in Table 8-7 can be interpreted as an OR<1 is "preventive"; OR=1 means no effect; OR>1 increases the chance of the outcome happening. The OR value for ANB was .504 so this is interpreted as with each additional degree of ANB, the odds of having greater than 2-mm of distal movement decreases by half. This signifies that patients with a more negative ANB experience or demonstrate more distalization.

The OR for PP to U1 was 1.36 and the OR for maxillary to mandibular incisor angulation was .88.

Table 8- 6: Significant Differences at T1 for Subjects with Greater than 2-mm of Molar Distalization

Associated with >2-mm change? (p-value from t-test)	
Before ceph	
SNA	0.50
SNPog	0.30
SNB	0.14
ANPog	0.06
ANB	0.01
PP to Ops	0.33
PP to ML	0.71
overjet	0.29
overbite	0.81
PP to U1	0.03
ML to L1	0.70
ils_lli	0.04
Mols/Moli	0.83
nst-sn-ls	0.10
ls-NCL	0.42
li-NCL	0.21

Table 8-7: Regression analysis for ANB, PP to U1, and ils-lli for Subjects with Greater than -2mm of Distal Molar Movement.

Logistic regression Number of obs = 20
LR chi2(3) = 8.49
Prob > chi2 = 0.0370
Log likelihood = -8.7061666 Pseudo R2 = 0.3277

bigchange	Odds Ratio	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ANB	.5041105	.1731953	-1.99	0.046	.257088	.9884843

```
Logistic regression                             Number of obs   =         20
                                                LR chi2(3)      =       7.26
                                                Prob > chi2     =     0.0641
Log likelihood = -9.3199616                     Pseudo R2       =     0.2803

------------------------------------------------------------------------------
   bigchange | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    PP to U1 |   1.362964   .2376717     1.78   0.076     .9683967    1.918297
------------------------------------------------------------------------------

Logistic regression                             Number of obs   =         20
                                                LR chi2(3)      =       4.84
                                                Prob > chi2     =     0.1842
Log likelihood = -10.530994                     Pseudo R2       =     0.1867

------------------------------------------------------------------------------
   bigchange | Odds Ratio   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
    ils_lli  |   .8852786   .0598228    -1.80   0.071     .7754609    1.010648
------------------------------------------------------------------------------
```

DISCUSSION

This retrospective study evaluated the results of 20 subjects that were treated with mandibular dental distalization utilizing TSADs for anchorage. The subject pool was entirely Taiwanese and was treated in National Taiwan University. The lateral head films assessed were taken at pretreatment (T1) and post-treatment (T2) time points. The second lateral ceph was not taken immediately after distalization of the mandibular dentition so all dental movement cannot be directly contributed to distalization mechanics, but rather to complete biomechanic Class III orthodontic correction as a whole.

These findings indicate several results in the treatment modality of mandibular dental distalization using TSADs in a non-growing mild class III patient. The evaluation of all 20 subjects in each of the treatment outcome indices resulted in a successful outcome. Although the PAR, ICON, and ABO-OGS cannot be compared to each other because of the different factors

that each evaluates, they have been validated in previous studies as predictable indicators of orthodontic outcome.[14,16,18] The results that were confirmed by these three indices validate the use of mandibular dental distalization in the correction of mild Class III patients. More studies will need to be done to confirm these findings and also to assess the long-term stability of this treatment.

Although mandibular dental distalization can achieve a successful outcome, it is important as a clinician to understand the detailed effects of this modality of treatment. While evaluating how the Class III was corrected, there were significant changes to the occlusal plane, overjet, maxillary incisor proclination, maxillary to mandibular molar and incisor angulation, nasolabial angle, and the upper lip position. It has been previously described by Enlow [19] that the cant of the occlusal plane compensates for skeletal discrepancies between jaws to attain a Class I occlusal relationship. This study also confirmed those findings by indicating a significant flattening of the occlusal plane by an average of 3.25 degrees. In a study by Donovan [20], he found that dentoalveolar compensation for skeletal Class III jaw discrepancies can be expressed as a counterclockwise rotational change in the dentoalveolar complex. This compensatory rotation would result in changes of proclination of the maxillary incisors, the change of the maxillary to mandibular incisor angulation, the increase of the nasolabial angle, and protrusion of the upper lip, which were all confirmed in this study. Although the values of these measurements may be out of the normal range, they may lie in a normal range for Class III skeletal discrepancies.

When evaluating the amount of distal movement of the mandibular dentition, it is important to focus on the type of movement that occurred. More specifically, how much distal horizontal tooth movement, tooth extrusion, or how much tooth inclination changed. From the

nine dental movements evaluated, it was found that the horizontal movement and inclination change of the mandibular incisors did not significantly change. This can be explained by work from a study by Kim [21]. Patients with a Class III skeletal discrepancy with normal overjet were compared to patients with a Class III skeletal discrepancy with negative overjet, and it was found that the mandibular inclination did not differ significantly between the two groups. It can also be further supported in a study by Bjork and Skieller [22] that reported the inclination of the mandibular incisors remained constant related to the sella-nasion plane despite rotation of the jaw due to the lip and tongue that maintained the functional incisal occlusion. The other seven tooth movements' evaluated had significant changes. The lower incisors, second bicuspids, and first molars all extruded about 1-mm which can be expected with any type of orthodontic treatment. The distal movement of the second bicuspid and the molar appear to be caused more by distal crown tipping and uprighting of the two teeth (see Figure 7-2).

In the evaluation of distal tooth movement, there was significant correlation of the angle of the palatal plane to the upper incisor (PP to U1) and the distal horizontal movement of the L5 and L6. It was found that for every increase of PP to U1, the distal horizontal movement increased by 0.47 and 0.46-mm, respectively. In a study evaluating dentoalveolar compensation in skeletal Class III patients, Kim [21] found that in positive overjet groups, the maxillary incisors were more proclined and the retroclination of the mandibular incisors was more pronounced. This study may help understand the correlation between the upper incisors and the distal movement of these mandibular teeth. This correlation may have been possible because these patients did not naturally experience this dentoalveolar compensation but did maintain the potential for this compensation to be completed orthodontically: thus, they had greater distalization achieved. Other data from this study that may further support this theory of "innate

potential" were the results from the regression analysis of the 7 subjects that experienced greater then 2-mm of distal horizontal tooth movement. These results concluded that if ANB increased by 1-degree, then the potential to distalize the mandibular molars greater then 2-mm decreased by 50%. It is important to remember that a positive ANB angle is a more Class II skeletal discrepancy. This study also concluded that for every unit of maxillary incisor proclination increase, then the potential to distalize the mandibular molars more than 2-mm increased by 36%. Another argument could be simply that the proclination of the upper incisors was a side effect of a Class III elastic biomechanic used to further distalize the mandibular dentition in more negative sagittal jaw relationship subjects.

CONCLUSION

1. In a mild class III non-growing patient, distalization of the mandibular dentition using TSAD anchorage can predictably achieve a successful orthodontic outcome supported by the PAR, ICON, and ABO-OGS validated indices.

2. All mandibular dental movement was highly significant except for the horizontal and inclination changes of the mandibular incisors. On average, the mandibular molars were distalized horizontally -1.95-mm and tipped -6.05 degrees, and the second premolars were distalized horizontally -2.27-mm and tipped -4.99 degrees. More studies will need to be completed on stability of this modality of treatment.

3. All patients experienced significant changes of the occlusal plane, overjet, maxillary incisor proclination, maxillary to mandibular molar and incisor angulation, nasolabial angle, and upper lip position. All these results can be expected in a compensatory treatment of a skeletal Class III patient treated to a Class I molar/canine relationship.

4. In a sample of 7 subjects that experienced on average 4-mm of molar distalization, there was a correlation between molar movement and the ANB angle, upper incisor proclination, and maxillary to mandibular incisor angulation.

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