THE EFFECTIVENESS OF INVISALIGN TREATMENT AS ASSESSED BY THE PAR INDEX AND THE AMERICAN BOARD OF ORTHODONTICS' STANDARDS

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ABSTRACT

Align Technology developed the Invisalign System in 1997, as an alternative to the traditional wire and bracket orthodontic therapy. Align is one of the first companies to use digital three-dimensional imaging of a patient's malocclusion in order to fabricate clear overlay aligners that facilitate tooth movement. These removable appliances must be worn full time and replaced every two weeks until the desired tooth movement is achieved. With such a new appliance, little research has been conducted to test the effectiveness of this appliance on treating malocclusions. The aim of this study was to assess the treatment improvement on selected cases treated solely with the Invisalign System. Also, the components of the malocclusion were analyzed to see where the System works most effectively. 25 patients with pre-and post-treatment final records were included in the sample. Treatment was carried out by five area private orthodontists.

The PAR Index, which shows excellent intra- and inter-examiner reliability was used to assess treatment change. Also the American Board of Orthodontics grading criteria was used to detect minor occlusal discrepancies following treatment. It was found that the mean percentage PAR reduction was 46.03%. This was statistically significant and further indicates successful treatment as shown by Richmond's category of improvement. 72% of the cases finished with acceptable alignment. The pre-treatment alignment showed only 24% with acceptable alignment, further indicating successful treatment. The maxillary and mandibular anterior alignment were the only components to show statistically significant treatment change($p < 0.05$). 28% of the cases passed the post-treatment ABO grading criteria (25 points). The occlusal contact score accounted for 27% of the post-treatment ABO score.

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LITERATURE REVIEW

Adult Orthodontics

In the past, the demand for adult orthodontic care had been small. However, within the last few years the adult population appears to be more interested in the benefits of treatment. In 1970, fewer than 5% of all orthodontic patients were over eighteen years old, but in the 1990's adults made up almost 15% of all orthodontic patients.[1] The most recent trend is seeing an increase in the older adult groups (age 40 an up) seeking treatment.[2] The demand for adult orthodontic care is expected to grow an additional 11% after another decade.[3]

Within the dental literature, controversy continues regarding the psychological effects of malocclusions and the potential treatment effects on patient's self image. Some negative or positive personality characteristics may be attributed to dental appearance.[38] Some studies have shown that dental appearance may be an important cue in assessing facial attractiveness.[7] A study in 1986 concluded that society has established norms for appropriate dental appearance and extreme deviations from these norms are defined by society as unacceptable.[5] According to Goffman[6], when one's physical attributes deviate too far from socially defined norms one may be disqualified from full social acceptance to the extent that one's life chances are reduced.

Despite recognizing the potential benefits of orthodontic correction, many adults are reluctant to seek treatment. Crowding and spacing are among the most common problems with adult dentitions, with crowding affecting about 24% of women and 14% of men, and spacing found in 8% of women and 13% of men.[4] Proffit believes that most adults in treatment have a more positive self-image than average, and that it must take a good deal of ego strength to seek out treatment. He goes on to say that the demand for invisible orthodontic appliances comes almost entirely from adults who are concerned about the reaction of others to obvious orthodontic appliances.[8]

Invisalign System

The idea of moving teeth with removable appliances has been around for some time. In 1945, Kesling[9] published an article describing the use of a series of planned, diagnostic waxed set-up models used in conjunction with elastic positioners to facilitate tooth movement. This was followed by Ponitz[10], McNamara[11], Rinchuse and Rinchuse[12], and Lindauer and Shoff[13]. But these methods were often labor intensive, time consuming and resulted in minimal orthodontic change.

In 1997, Align Technology, headquartered in Santa Clara, California, developed the Invisalign System as an alternative to conventional "wire and bracket" orthodontic therapy. The technology uses computer aided design models based on three-dimensional imaging of an individuals malocclusion.[14] Invisalign claims that a skilled orthodontist can use the Invisalign System to treat a vast majority of patients who want a better, more esthetical smile.

Invisalign has two components: ClinCheck and the Aligners. ClinCheck is the internet-based application that allows the orthodontist to simulate the proposed treatment. Through the digital imaging, a series of algorithmic stages are produced which move the teeth in a sequence of precise movements(0.15-0.25mm), or stages. Stereolithic models are then constructed for each stage of treatment. Clear overlay appliances(or "aligners") of 0.030-inch thickness are worn sequentially by the patient for approximately 2 weeks then changed to the next set, until the desired tooth alignment is achieved.[15] The number of aligners needed for each case depends on the extent of tooth movement required. These "aligners" correspond to each stage of the ClinCheck simulation.

Currently, the initial diagnosis for orthodontic treatment is made by the clinician. Once a diagnosis has been made, an accurate, polyvinylsiloxane(PVS) impression is made of both arches. The impression as well as a wax bite, appropriate radiographs, photographs, and proposed treatment plan are sent to the

manufacturer. Once the impressions are poured and digitally imaged, the computerized treatment plan becomes accessible for the clinician, through the ClinCheck internet application. The clinician has the option of accepting the treatment plan or requesting modification to the virtual plan. Any modifications to the plan are reviewed by an Align staff orthodontist. Once the treatment plan is agreed upon by both Align and the clinician, the aligners are fabricated and mailed to the clinician, for delivery to the patient.

Some patients require bonding composite attachments to their teeth to facilitate more difficult movements such as tooth extrusion, intrusion, extraction space closure or alignment of severely rotated teeth. Patient visits are similar to fixed appliance therapy visits and include evaluation of the hygiene, occlusion, alignment and patient compliance. After the desired alignment is attained, a decision to perform any further refinement in the occlusion is determined. If further refinement is necessary, a new PVS impression must be made and sent for rescanning to allow for refinement aligners.

Align Technology began marketing their Invisalign System to orthodontists in July, 1999 and to General Dentists in early 2002. With such a new product, little time has elapsed to carefully document its effectiveness. Align claims to have conducted a number of private and university-based clinical studies across the U.S. prior to commercially releasing their product. Some documented studies include several case reports.

In April of 2000, Boyd[39] wrote about the treatment success of four cases treated with the Invisalign System. All were adults with minor crowding or spacing. The paper concluded "that the Invisalign System has opened up a new area of adult orthodontics, serving patients who may not want the traditional fixed appliances". One limitation noted from this report included an increased incidence of posterior openbite(0.25-0.50mm) due to tooth intrusion from the occlusal coverage of the aligners. In March of 2001, Boyd[40] published another case study of a thirty-five year old male who underwent Invisalign treatment for correction of

4-5mm of maxillary and mandibular crowding. Boyd concluded that "when evaluating the occlusal outcome of this case, it is evident that conventional fixed or removable appliances could have achieved the same or better occlusal result in arguably less time. The major advantage of the Invisalign appliance is clearly its esthetic, removable nature". Owen[41] published a case report describing correction of minor crowding with the Invisalign System. He used the appliance on himself in an accelerated fashion, in which he changed his aligners every three days as well as having corticotomy-assisted surgery. In this incident, because the treatment proceeded so fast, no posterior intrusion resulted.

Boyd published another paper in December, 2001, with several comments relating to the Invisalign System experience. He stated that based on their results so far, treatment outcome is highly dependent on clinician experience, as well as specific case selection.[15] This appears to contradict recent advertisement by Align Technology with the claim that "No prior orthodontic experience is necessary" and that this system is "the most significant new esthetic procedure since bleaching and almost as simple".[42] It should be noted that this appliance is compliant dependent and not suitable for erupting dentitions. Other findings from Boyd included a subjective evaluation of patient discomfort during treatment to show less discomfort than what the authors had seen with traditional fixed appliances. "This is most likely because the magnitude of the tooth movements are only 0.2mm, on average".[15] According to Boyd, the current appliance has both limitations and advantages. The greatest advantage is believed to be the improved esthetics and the ability to remove the appliance. This allows for better hygiene control and gives the patient the opportunity to bleach the teeth during treatment. Boyd believes treatment time is equivalent to fixed appliance duration. However, several limitations are discussed by Boyd. He states that, currently, only crown position is displayed on the computer program. Because the clinical appearance of crown inclination is not always predictive of root inclination, the potential exists for a virtual treatment to be approved, in which crown position appears optimal

but root position is not ideal. He also states that once the treatment plan is initiated, it can not be modified without increasing both the cost and time of treatment. And lastly, the cost of this appliance is greater than for fixed appliances, but the doctor's chair time and instrument sterilization costs should be significantly lower.

Boyd believes that this appliance, as true of most removable appliances, tends to be most efficient at tipping teeth. If bodily movement of the teeth are necessary, it must be treatment planned initially requiring composite attachments to aid with proper biomechanics. Correction of deep overbite appears to be a fairly predictable movement. Boyd also believes that molar distalization, followed by the premolars and the canines is another possibility but extrusion has proven to be one of the most difficult movements. It should be noted that Dr. Boyd has a stated financial interest with Align Technology.[15]

Align Technology anticipates that the range of applicability of their system will broaden as a result of on-going studies. The University of the Pacific is currently studying the effects of Invisalign treatment on various malocclusions which are currently outside Align's case selection criteria. This includes premolar extractions, anterior open bites, and severe rotations. The University of Indiana is measuring the loads applied by the aligners for tooth movement and collecting such data to estimate future tooth movement using Finite Element Analysis(FEA). The University of Florida is conducting a randomized clinical trial to study the attachments needed for extrusions, intrusions and rotations. And finally, the University of Washington is conducting a randomized clinical trial to study the effectiveness of different materials and different treatment times.

Orthodontic Standards

The measured success of orthodontic treatment is difficult to obtain. This difficulty stems from the measurements used, as most are collected subjectively and therefore open to various opinions. Isaacson asks "should we passively allow the consumer to establish the standards of care for orthodontists?" He answers "It is important for us to document what we consider acceptable."[16] Atta believes that serving quality is serving excellence. It is the assurance that every patient, regardless of the type of malocclusion, is treated to the predictable outcome in a short time, with less cost, and that the results attained meet professional standards and exceed patient expectation.[17]

In 1996, the American Association of Orthodontists(AAO) tried to embody a uniformed goal for clinical orthodontists when they developed the Clinical Practice Guidelines for Orthodontics and Dentofacial Orthodpedics.[19] Although they did not produce standards of care, they did implement treatment goals as "optimum dentofacial function, health, stability and esthetics". They also listed the following positive outcomes of orthodontic treatment:

1)Satisfaction of the patient's chief complaint.

2)Well-aligned teeth.

3)Good or improved occlusal function.

4)Good or improved dental facial esthetics.

5)Good or improved environment for dentofacial development.

6)Desirable modification of the size, shape, and position of the jaws.

7)Stability of treatment results.

8)Good or improved dental and periodontal health.

The issue of how to measure such treatment goals has been a debated topic throughout the orthodontic literature.

Occlusal Indices

The concept of occlusion was developed in the late 1800's in order to make better prosthetic replacement teeth.[2] As the paradigm shift from replacing teeth to restoring and maintaining the natural teeth was being made, Edward H. Angle published his classification of malocclusion in the 1890's.[20] Angle used the presumed constancy of the position of the maxillary first molar in relation to the mandibular first molar to develop his standard. Angle's system has been widely criticized for displaying a lack of quantitative meaning[21], an inability to relate malocclusion with facial balance[22], and a failure to relate malocclusion in three dimensions.[23] Katz looked at eight popular indices, including Angle's classification, in terms patient satisfaction based on occlusal designation. What he found was that Angle's classification had the strongest correlation with the patient's satisfaction.[24] Despite many criticisms, Angle's classification has proven to be the most widely used indicator of the prevalence of malocclusion in various populations.[49]

Larry Andrews[25] decided to take Angle's classification a few steps forward. He looked at 120 casts of nonorthodontic patients with normal occlusions ("patients who would not benefit from orthodontic treatment"). He was looking for consistency of characteristics that made these cases ideal. He discovered six traits that he believed could be used as standards against which deviations from ideal alignment could be identified and measured. He believed that "if one knew what constituted 'right,' then he could directly, consistently, and methodically identify and quantify what was wrong".

Shaw et al[48] suggested that there are five types of indices with distinct purposes. The first would be a diagnostic classification such as Angle's molar classification. Second would be the epidemiological indices such as the Dento-facial index(DFI)[26], the Index of Tooth Position[27], the Malalignment Index(MI)[28], the Occlusal Feature Index(OFI)[29], and Bjork's[30] computer analysis. A third index category would be one of treatment need. This would include the Handicapping

Labio-lingual Deviation Index[31], the Handicapping Malocclusion Assessment Record (HMAR)[32], Summer's Occlusal Index[33], Freer's Multivariate technique[34], the Sweedish prescription[35] for orthodontic need, the Index of Orthodontic Treatment Need(IOTN)[36], and the Standardized Continuum of Aesthetic Need(SCAN)[37]. A fourth index category would measure treatment success. This would include Eismann's morphological criteria, Gottlieb's method of grading your orthodontic results, Berg's method of assessing skeletal and dental outcome, the Peer Assessment Rating, and the American Board of Orthodontics' standards. A fifth category of assessing treatment complexity has yet to be designed. Since the current study aims to determine treatment effectiveness of the Invisalign System, we will confine our discussion of indices to the fourth category.

The World Health Organization summarized the requirements for all dental indices in 1966.[44] The following is a list of the main requirements for an index of occlusion:

1. *Reliability.* The index should be reproducible by other examiners or by the same examiner at some other point in time.

2. *Validity.* The index should measure what it was intended to measure

3. *Validity during time.* The index should consider the normal development of occlusion.[33]

In 1974, Eismann described a method of evaluating the effectiveness of orthodontic treatment based on fifteen morphological criteria.[43] Points were assigned to each condition registered and the total points were summed to give a score that indicated the morphological problems. The more severe conditions received higher scores. The method was criticized for the subjectivity involved in assigning points.

In 1975, Gottlieb published an article on a method for grading your orthodontic treatment results.[45] He used a standard group of tooth relationships

that are generally accepted as criteria in establishing orthodontic correction. The characteristics are:

1. Class I molar relationship
2. Class I cuspid relationship
3. Cusp interdigitation
4. Overbite
5. Overjet
6. Midline
7. Rotation
8. Crowding or spacing
9. Arch Form
10. Torque and parallelism

In evaluating treatment results, Gottlieb compared before and after treatment models. For each characterstic, he assigned the following grades:

5 points-condition corrected
3 points-condition almost corrected
1 point- condition half corrected
0 points-condition not corrected
-1 point-condition worsened.

A percentage achievement was obtained which related to the factors requiring correction at the commencement of treatment. He interpreted the grades as follows:

85% or better-good
75%-85%-satisfactory
65%-75%-mediocre
50%-65%-poor
less than 50%-unsatisfactory.

This method of grading has been criticized[46] for being biased towards improvement because five points were allotted for full correction of a feature but only a single point was deducted for a worsening of the condition.

Berg [47] looked at 264 consecutively treated orthodontic cases to evaluate treatment success based on skeletal and dental outcomes. For all cases the

classification of good results was based on the following criteria: (a) Normal sagittal, vertical and transverse occlusion; (b) Dental alignment without rotations exceeding 10° or (extraction) spaces of more than 1mm in one quadrant; (c) Reasonably good axial inclination; and (d) Apical root resorption not exceeding 1mm. Treatment results that met the above criteria were classified as A-cases and referred to as cases where the optimal treatment objective had been achieved. Cases which failed to meet the objectives were classified as B-cases. However, the inclusion of root resorption should be done with reservation because the assessment of resorption from radiographs as well as the cause of the resorption are open to speculation. Also, the validity of the proposed ideal treatment goal may be questioned on an epidemiological basis since it is well known that only a minority of the population has an ideal occlusion.

All three of the previously mentioned indices compare pre-treatment to post-treatment records to register the outcome of orthodontic treatment. However, the reliability and validity of these indices has been questioned. According to Richmond et al[48], none of the aforementioned indices has been universally accepted. "The use of precise criteria is essential, requiring a quantitative objective method of measuring malocclusion and efficacy of treatment". He goes on to say that to fulfill these criteria the PAR (Peer Assessment Rating) Index was developed to record the malocclusion at any stage of treatment.

The Peer Assessment Rating(PAR) Index

A group of ten experienced British orthodontists developed the PAR Index in 1987.[50] Two hundred dental casts representing pre- and post-treatment stages were analyzed until it was decided which factors would be utilized in estimating the best alignment of occlusion. Since then, the PAR index has been used extensively in Europe as an audit of orthodontic quality,[51,52] and in a more limited use in the United States.

The PAR Index system assigns a score to different occlusal traits within the malocclusion. The scores are summed to represent the degree that a case deviates from ideal alignment. A score of zero would represent an excellent alignment. As the malocclusion becomes more severe, the score will increase due to the discrepancies in alignment. The PAR Index can show improvement of a malocclusion by two ways: (1) total point reduction in the PAR score and (2) percentage reduction in the PAR score.[53] The PAR Index has also been shown to have excellent intra- and interexaminer reliability, with intraclass correlation coefficients of .95 and .91, respectively.[50] The PAR Index is made up of eleven components.(Table 1)

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.	Midline
11.	Left buccal occlusion

Table 1. Components of the PAR Index.

Buccal and Anterior Segments

The maxillary and mandibular arches are divided into right and left buccal segments and an anterior segment. The amount of crowding, spacing, and impacted teeth are recorded with a specially designed ruler made specifically to facilitate the PAR measurements. The recording zone for the anterior segments extends from the mesial contact of one canine to the mesial contact of the adjacent canine. The buccal segment zone extends from the distal contact of the canines posteriorly to the mesial contact of the first molar. The displacements are measured as the smallest distance between contact points of adjacent teeth.(Table 2)

Score	Discrepancy
0	0mm to 1mm
1	1.1mm to 2mm
2	2.1mm to 4mm
3	4.1mm to 8mm
4	greater than 8mm
5	impacted teeth

Table 2. Displacement scores for buccal and anterior segments.

Buccal Occlusion

The buccal occlusion is recorded for both the left and right sides with respect to the three planes of space (Table 3). The recording zones is from the canine to the last molar in the mouth. The antero-posterior, vertical and transverse discrepancies are summed for each buccal segment.

Score	Discrepancy
Antero-posterior	
0	Good interdigitation Class I, II, and III
1	Less than half unit discrepancy
2	Half a unit discrepancy (cusp to cusp)
Vertical	
0	No discrepancy in intercupation
1	Lateral open bite on at least two teeth greater than 2mm
Transverse	
0	No cross-bite
1	Cross-bite tendency
2	Single tooth in cross-bite
3	More than one tooth in cross-bite
4	More than one tooth in scissor bite

Table 3. Buccal occlusal disrepancy scores

Overjet

Positive overjet (Table 4) of the most prominent aspect of any one lateral or central incisor is recorded. Crossbites are also recorded. The same case may have points added for excess overjet and crossbites.

Score	Discrepancy
Overjet	
0	0-3mm
1	3.1-5mm
2	5.1-7mm
3	7.1-9mm
4	greater than 9mm
Anterior cross-bites	
0	No discrepancy
1	One or more teeth edge to edge
2	One single tooth in cross-bite
3	Two teeth in cross-bite
4	More than two teeth in cross-bite

. **Table 4.** Overjet scores.

Overbite

Records the vertical overlap or open bite of the anterior teeth(Table 5). This records in relation to the coverage of the lower incisors or the degree of open bite, from lateral incisor to lateral incisor. The tooth with the greatest overlap and/or open bite is recorded. The canines are included if in cross-bite.

Score	Discrepancy
Open bite	
0	No open bite
1	Open bite less than and equal to 1mm
2	Open bite 1.1-2mm
3	Open bite 2.1-3mm
4	Open bite greater than or equal to 4mm
Overbite	
0	Less than or equal to one third coverage of the lower incisor
1	Greater than one-third, but less than two-thirds coverage of lower incisor
2	Greater than two-thirds coverage of the lower incisor
3	Greater than or equal to full tooth coverage

Table 5. Overbite scores.

Midlines

This measure records the midline discrepancy (Table 6) in relation to the lower central incisor. Lower central incisor extractions are not included in the scoring.

Score	Discrepancy
0	Coincident and up to one-quarter lower incisor width
1	One-quarter to one-half lower incisor width
2	Greater than one-half lower incisor width

Table 6. Midline scores.

The designers of the PAR Index established a weighting system based on the statistically sampled components of the Index. What they found was that some of the components making up PAR Index did not appear to have any predictive power and were eliminated from the weighted PAR Index. The weighted components gave a statistically higher correlation with the average deviation from normal occlusion than did the unweighted PAR ($P<0.001$).[50] The mean weightings were taken to represent the collective opinion of seventy four British dentists who were involved in initial design testing of the PAR index. The United States also performed a validation exercises for the PAR with eleven private practicing orthodontists from Pennsylvania.[54] In the U.S. study, the lower labial segment alignment was not weighted. The present study uses only the British (UK) weightings (Table 7).

PAR components	Un-weighted	UK Weighted	US Weighted
Buccal segments	1	0	0
Upper anterior	1	1	1
Lower anterior	1	1	0
R and L buccal occlusion	1	1	2
Overjet	1	6	5
Overbite	1	2	3
Midline	1	4	3

Table 7. Un-weighted and weighted individual PAR components.

Richmond states that a 30% reduction in the weighted PAR score is required for the case to be deemed as improved. He believes that a score of ten would represent acceptable alignment and five or better would be close to ideal occlusion. He also states that a case which shows a point reduction greater than twenty two points is considered to be greatly improved.

The American Board of Orthodontic's Grading System

The American Board of Orthodontic's grading system was developed through a series of four field tests over a span of four years. In 1995, 100 cases were selected from the phase III ABO examination and evaluated by measuring fifteen criteria on each final dental cast and panoramic radiograph. The evaluation revealed that 85% of the deficiencies in the final results occurred in seven of 15 criteria which included alignment, marginal ridges, buccolingual inclination, overjet, occlusal relationships, occlusal contacts, and root angulation.

In 1996, another field test was conducted to determine the reliability of the established grading criteria with multiple examiners. Four Directors evaluated 300 sets of post treatment dental casts and panoramic radiographs. Once again, the previous inadequacies occurred in the seven identified categories. At this time, it was recommended that a precise measuring instrument be developed to account for the highly variable inter-examiner reliability.

In 1997, a third field test was conducted using the new measuring device. A calibration class was also conducted prior to examination to help with the reliability and to establish more accurate measurements for the ABO Directors. 832 dental casts were evaluated and the same seven problem areas were identified. The Directors decided to add interproximal contacts to the scoring scheme and to modify the measuring device.

The fourth and final field test was conducted in 1998, with all of the ABO Directors participating in the evaluation process. The test was successful at "reaffirming the benefits of using an objective system for grading the dental casts and panoramic radiographs, but also helping to establish standards for successful completion of this portion of the phase III ABO examination.

It was determined that a total score of less than 20 is considered passing. A case that loses more than 30 points will fail. Furthermore, a case that scores between 20 and 30 points falls into a gray area in which the directors of the Board

will evaluate other circumstances such as case complexity, diagnosis, quality of the records, facial profile, radiographic analysis and treatment plan, in establishing a passing score. The current study used 25 as the passing rate for the ABO score. This represented the middle of the ABO's "gray area" for acceptability.

In addition to preparing cases for the phase III examination, the ABO states that orthodontists may use this scoring system at anytime in their orthodontic career to determine if they are producing "Board quality" results. They also state that this method of self-evaluation will help to elevate the quality of orthodontic care in the future.[55]

PURPOSE OF STUDY

The Invisalign system was never designed as a universal panacea for treating all malocclusions. It was, however, designed to treat specially screened cases with non-erupting dentitions of patients who otherwise, would not elect fixed orthodontic treatment. With the recent widespread introduction of the various occlusal indices used for the objective assessment of treatment success, it seems appropriate to determine the effectiveness of this latest technology.

The current study aims to assess the improvement produced in selected cases treated solely with the Invisalign System. It also attempts to determine in which circumstances the Invisalign System works most successfully and efficiently.

MATERIALS AND METHODS

Twenty seven patients whose treatment was consecutively completed by five private orthodontists in the greater Portland, Oregon area who met the following criteria, were included in this study. Each subject was required to have pre-treatment and post-treatment study models with appropriate wax bite registrations. If possible, final panoramic radiographs should be included in the final records. The subjects should have been exclusively treated with Align Technology's Invisalign System during the field of study. Two of the subjects were eliminated from the sample due to inadequacies of the final treatment records and from over-contoured permanent restorations that would have skewed treatment outcome if included in the sample. Four of the five orthodontists performing the treatment are Diplomates of the American Board of Orthodontics and all are Invisalign certified.

The following information was recorded for each subject included in the study:

1) The Pre-treatment PAR score
2) The Post-treatment PAR score
3) The Post-treatment ABO score
4) The Pre-treatment ABO score(if post-treatment ABO score deemed passed)
5) Age, Sex, initial molar classification, number of aligners used during treatment, number of refinement aligners used to finish treatment, and treatment duration (Table 8)

Twenty five cases were included in the final sample. There were 7 males and 18 females with an average age of 32.5 years. The oldest patient was 51.7 years and the youngest was14.1 years. 23 cases began treatment as Angle Class I with generalized crowding. 1 case was Angle Class II and 1 other case was Angle Class II, subdivision left. The average treatment time for the cases was 11.54

months ± 3.47 months, with the longest duration being 19 months and the shortest treatment duration being 6 months.

The average number of Invisalign aligners used to facilitate treatment was 16.24 ± 4.82 in the maxillary arch and 17.72 ± 5.45 in the mandibular arch. 8 cases studied used refinement aligners to finish their treatment. The average number of refinement aligners used was 0.96 ± 2.19 in the maxillary arch and 1.44 ± 2 .58 in the mandibular arch.

Assessment of all the PAR and ABO scores was determined solely by the author. The usefulness of these grading systems depends not only on their objectivity, but more importantly on the validity and reliability of the measurements. The reliability will be insured through the use of the PAR ruler and the precise ABO measuring device. Also, the author had been trained in use of the PAR Index and was calibrated for the ABO scoring. To confirm reliability in this study, 10 sets of study models were selected randomly and reassessed on a second occasion by the author, without reference to the original results. The intra-examiner agreement was checked using the Pearson correlation coefficient. The Pearson correlation coefficient for the Pre-treatment PAR scores was 0.96 and the post-treatment PAR score was 0.98. The post-treatment ABO score had a correlation coefficient of 0.95. The intra-examiner error can thus be considered negligible.

All statistical analyses were carried out using the SPSS software. The British-based weighting system for the PAR score was used for the statistical analysis so that the lower labial segment alignment could be taken into account.

CASE	PATIENT AGE (Years)	SEX	MOLAR CLASS	ALIGNERS (Max.)	ALIGNERS (Mand.)	REFINEMENT (Max.)	REFINEMENT (Mand.)	TX DURATION (Months)
1	24.6	F	II	12	13	4	4	8
2	14.8	F	I	14	18	0	0	12
3	17.6	F	I	18	22	3	3	14.5
4	26.3	M	I	10	13	0	3	14.5
5	40.8	F	I	15	10	0	0	7.5
6	36.3	M	I	15	22	9	9	12
7	15.5	M	I	22	18	0	0	12
8	15	F	I	20	20	0	6	18
9	26.3	F	I	9	14	0	0	7
10	34	F	II, Sub. L.	14	13	4	0	13
11	17.4	M	I	18	18	0	0	8
12	25.5	F	I	25	30	0	5	17.5
13	29.8	F	I	27	25	0	0	14
14	47.2	F	I	22	22	0	0	9.5
15	47	M	I	21	20	0	0	13
16	39.3	F	I	13	18	0	0	11
17	32.9	F	I	17	22	0	0	11
18	34.3	F	I	11	9	0	0	7
19	46.3	F	I	12	12	0	0	6
20	40.7	F	I	13	19	0	0	10
21	40	F	I	19	24	0	0	12
22	51.7	F	I	15	8	0	0	11
23	46.7	F	I	14	22	4	6	19
24	14.1	M	I	10	13	0	0	9
25	48.2	M	I	20	18	0	0	12
MEAN	32.492			16.24	17.72	0.96	1.44	11.54
STD. DEV.	12.22183565			4.824	5.4507	2.189	2.5833	3.469870315
MAX	51.7			27	30	9	9	19
MIN	14.1			9	8	0	0	6

Table 8. Sample characteristics and treatment information.

RESULTS

Data from both the un-weighted pre- and post-treatment PAR scores are included in Tables 9 and 10. The British (UK) weighted PAR scores are included in Table 11 and 12.

CASE	UPPER LABIAL	LOWER LABIAL	LEFT BUCCAL OCCLUSION			RIGHT BUCCAL OCCLUSION			OVERJET		OVERBITE		MIDLINE	TOTAL
			Ant/Post	Vertical	Transverse	Ant/Post	Vertical	Transverse	Overjet	Crossbite	Open bite	Overbite		
1	2	4	7	0	0	8	0	0	2	0	0	2	1	26
2	2	3	0	0	0	1	0	0	2	0	0	1	1	10
3	2	1	3	0	0	3	0	0	0	0	0	0	0	9
4	0	1	0	0	0	1	0	0	0	0	0	0	0	2
5	5	1	1	0	0	1	0	0	0	0	0	1	0	9
6	4	4	3	0	0	1	0	0	1	0	0	1	1	15
7	3	1	1	0	0	0	0	0	1	0	0	1	0	7
8	2	3	0	0	1	1	0	0	0	0	0	1	0	8
9	1	0	0	0	0	0	0	0	0	0	0	1	0	2
10	3	2	8	0	0	10	0	0	1	0	0	2	0	26
11	1	6	2	0	0	2	0	0	1	0	0	2	0	14
12	4	6	4	0	0	1	0	0	3	0	2	0	1	21
13	3	1	1	0	0	1	0	0	2	0	1	0	0	9
14	5	2	4	0	0	1	0	0	2	0	0	1	0	15
15	6	5	2	2	2	1	1	3	1	0	0	0	0	23
16	1	3	2	0	0	0	0	0	2	0	2	0	0	10
17	3	6	3	0	0	2	0	0	1	0	0	0	0	15
18	3	1	3	0	0	0	0	0	1	0	0	1	0	9
19	2	1	0	0	0	5	0	0	1	0	0	1	0	10
20	4	2	0	0	0	0	0	0	1	0	0	0	0	7
21	3	2	1	0	0	1	0	0	0	0	0	1	0	8
22	3	4	1	0	0	0	0	0	0	0	0	0	1	9
23	1	3	3	0	0	3	0	0	1	0	0	1	0	12
24	4	5	1	0	0	0	0	0	1	0	0	1	1	13
25	2	5	0	0	0	0	0	0	1	0	0	0	0	8
MEAN	2.76	2.88	2	0.08	0.12	1.72	0.04	0.12	1	0	0.2	0.72	0.24	11.9
ST.DEV.	1.45	1.86	2.121	0.4	0.4397	2.509	0.2	0.6	0.82	0	0.577	0.68	0.436	6.39
MAX	6	6	8	2	2	10	1	3	3	0	2	2	1	26
MIN	0	0	0	0	0	0	0	0	0	0	0	0	0	2

Table 9. Pre-treatment un-weighted PAR scores.

CASE	UPPER LABIAL	LOWER LABIAL	LEFT BUCCAL OCCLUSION			RIGHT BUCCAL OCCLUSION			OVERJET		OVERBITE		MIDLINE	TOTAL
			Ant/Post	Vertical	Transverse	Ant/Post	Vertical	Transverse	Overjet	Crossbite	Open bite	Overbite		
1	0	0	7	0	0	8	0	0	2	0	0	2	0	19
2	0	0	0	0	0	0	0	0	1	0	0	1	0	2
3	0	0	2	0	0	2	0	0	0	0	0	0	0	4
4	0	0	0	0	0	1	0	0	0	0	0	0	0	1
5	0	0	1	0	0	1	0	0	0	0	0	1	0	3
6	0	1	2	0	0	3	0	0	1	0	0	0	1	8
7	0	1	2	0	0	3	0	0	0	0	0	1	0	7
8	1	0	2	1	0	3	0	0	0	0	0	1	0	8
9	0	0	2	0	0	0	0	0	0	0	0	1	0	3
10	1	1	9	0	0	9	2	0	1	0	0	1	0	24
11	1	0	4	0	0	1	0	0	1	0	0	1	0	8
12	0	0	0	1	0	0	1	0	1	0	1	0	0	4
13	0	1	2	1	0	0	2	0	1	0	0	1	0	8
14	0	0	4	0	0	1	0	0	0	0	0	0	0	5
15	2	3	1	2	1	0	1	1	1	0	0	0	0	12
16	1	0	1	1	0	0	0	0	0	0	1	0	0	4
17	1	1	1	0	0	1	0	0	0	0	0	0	0	4
18	0	0	3	0	0	3	1	0	0	0	0	0	0	7
19	2	0	0	0	0	6	1	0	1	0	0	1	0	11
20	0	1	2	0	0	0	0	0	1	0	0	0	0	4
21	0	0	2	0	0	1	0	0	0	0	0	0	0	3
22	0	0	1	0	0	0	1	0	0	0	0	0	0	2
23	0	0	3	0	0	3	0	0	0	0	1	0	0	7
24	0	0	1	2	0	1	1	0	0	0	0	1	0	6
25	0	1	0	1	0	0	0	0	0	0	0	0	0	2
MEAN	0.36	0.4	2.08	0.36	0.04	1.88	0.4	0.04	0.44	0	0.12	0.48	0.04	6.64
ST.DV	0.64	0.71	2.139	0.64	0.2	2.489	0.65	0.2	0.58	0	0.332	0.59	0.2	5.34
MAX	2	3	9	2	1	9	2	1	2	0	1	2	1	24
MIN	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 10. Post-treatment un-weighted PAR scores.

CASE	UPPER	LOWER	LEFT BUCCAL OCCLUSION			RIGHT BUCCAL OCCLUSION			OVERJET		OVERBITE		MIDLINE	TOTAL
	LABIAL	LABIAL	Ant/Post	Vertical	Transverse	Ant/Post	Vertical	Transverse	Overjet	Crossbite	Open bite	Overbite		
1	2	4	7	0	0	8	0	0	12	0	0	4	4	41
2	2	3	0	0	0	1	0	0	12	0	0	2	4	24
3	2	1	3	0	0	3	0	0	0	0	0	0	0	9
4	0	1	0	0	0	1	0	0	0	0	0	0	0	2
5	5	1	1	0	0	1	0	0	0	0	0	2	0	10
6	4	4	3	0	0	1	0	0	6	0	0	2	4	24
7	3	1	1	0	0	0	0	0	6	0	0	2	0	13
8	2	3	0	0	1	1	0	0	0	0	0	2	0	9
9	1	0	0	0	0	0	0	0	0	0	0	2	0	3
10	3	2	8	0	0	10	0	0	6	0	0	4	0	33
11	1	6	2	0	0	2	0	0	6	0	0	4	0	21
12	4	6	4	0	0	1	0	0	18	0	4	0	4	41
13	3	1	1	0	0	1	0	0	12	0	2	0	0	20
14	5	2	4	0	0	1	0	0	12	0	0	2	0	26
15	6	5	2	2	2	1	1	3	6	0	0	0	0	28
16	1	3	2	0	0	0	0	0	12	0	4	0	0	22
17	3	6	3	0	0	2	0	0	6	0	0	0	0	20
18	3	1	3	0	0	0	0	0	6	0	0	2	0	15
19	2	1	0	0	0	5	0	0	6	0	0	2	0	16
20	4	2	0	0	0	0	0	0	6	0	0	0	0	12
21	3	2	1	0	0	1	0	0	0	0	0	2	0	9
22	3	4	1	0	0	0	0	0	0	0	0	0	4	12
23	1	3	3	0	0	3	0	0	6	0	0	2	0	18
24	4	5	1	0	0	0	0	0	6	0	0	2	4	22
25	2	5	0	0	0	0	0	0	6	0	0	0	0	13
MEAN	2.76	2.88	2	0.08	0.12	1.72	0.04	0.12	6	0	0.4	1.44	0.96	18.5
ST.DV.	1.451	1.856	2.121	0.4	0.4397	2.509	0.2	0.6	4.9	0	1.155	1.356	1.744	10.2
MAX	6	6	8	2	2	10	1	3	18	0	4	4	4	41
MIN	0	0	0	0	0	0	0	0	0	0	0	0	0	2

Table 11. Pre-treatment British weighted PAR scores.

CASE	UPPER	LOWER	LEFT BUCCAL OCCLUSION			RIGHT BUCCAL OCCLUSION			OVERJET		OVERBITE		MIDLINE	TOTAL
	LABIAL	LABIAL	Ant/Post	Vertical	Transverse	Ant/Post	Vertical	Transverse	Overjet	Crossbite	Open bite	Overbite		
1	0	0	7	0	0	8	0	0	12	0	0	4	0	31
2	0	0	0	0	0	0	0	0	6	0	0	2	0	8
3	0	0	2	0	0	2	0	0	0	0	0	0	0	4
4	0	0	0	0	0	1	0	0	0	0	0	0	0	1
5	0	0	1	0	0	1	0	0	0	0	0	2	0	4
6	0	1	2	0	0	3	0	0	6	0	0	0	4	16
7	0	1	2	0	0	3	0	0	0	0	0	2	0	8
8	1	0	2	1	0	3	0	0	0	0	0	2	0	9
9	0	0	2	0	0	0	0	0	0	0	0	2	0	4
10	1	1	9	0	0	9	2	0	6	0	0	2	0	30
11	1	0	4	0	0	1	0	0	6	0	0	2	0	14
12	0	0	0	1	0	0	1	0	6	0	2	0	0	10
13	0	1	2	1	0	0	2	0	6	0	0	2	0	14
14	0	0	4	0	0	1	0	0	0	0	0	0	0	5
15	2	3	1	2	1	0	1	1	6	0	0	0	0	17
16	1	0	1	1	0	0	0	0	0	0	2	0	0	5
17	1	1	1	0	0	1	0	0	0	0	0	0	0	4
18	0	0	3	0	0	3	1	0	0	0	0	0	0	7
19	2	0	0	0	0	6	1	0	6	0	0	2	0	17
20	0	1	2	0	0	0	0	0	6	0	0	0	0	9
21	0	0	2	0	0	1	0	0	0	0	0	0	0	3
22	0	0	1	0	0	0	1	0	0	0	0	0	0	2
23	0	0	3	0	0	3	0	0	0	0	2	0	0	8
24	0	0	1	2	0	1	1	0	0	0	0	2	0	7
25	0	1	0	1	0	0	0	0	0	0	0	0	0	2
MEAN	0.36	0.4	2.08	0.36	0.04	1.88	0.4	0.04	2.64	0	0.24	0.96	0.16	9.56
ST.DV.	0.638	0.707	2.139	0.64	0.2	2.489	0.65	0.2	3.5	0	0.663	1.172	0.8	7.87
MAX	2	3	9	2	1	9	2	1	12	0	2	4	4	31
MIN	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 12. Post-treatment British weighted PAR score.

The mean British (UK) weighted percentage reduction in PAR score for the sample was 46.03% ± 30.95%(Table 13) The maximum percentage reduction was 84.62% and the minimum percentage reduction was –33.33%. The mean British weighted point reduction was 8.96 ± 7.41%. The maximum point reduction was 31 and the minimum point reduction was –1. 22 of the cases showed a positive point reduction, 1 case showed no change and 2 cases showed a negative point reduction

CASE	UNWEIGHTED PAR		UK WEIGHTED PAR		UK PAR POINT	UK PAR %
	Pre-Tx	Post-Tx	Pre-Tx	Post-Tx	REDUCTION	REDUCTION
1	26	19	41	31	10	24.39
2	10	2	24	8	16	66.67
3	9	4	9	4	5	55.56
4	2	1	2	1	1	50
5	9	3	10	4	6	60
6	15	8	24	16	8	33.33
7	7	7	13	8	5	38.46
8	8	8	9	9	0	0
9	2	3	3	4	-1	-33.33
10	26	24	33	30	3	9.09
11	14	8	21	14	7	33.33
12	21	4	41	10	31	75.61
13	9	8	20	14	6	30
14	15	5	26	5	21	80.77
15	23	12	28	17	11	39.29
16	10	4	22	5	17	77.27
17	15	4	20	4	16	80
18	9	7	15	7	8	53.33
19	10	11	16	17	-1	-6.25
20	7	4	12	9	3	25
21	8	3	9	3	6	66.67
22	9	2	12	2	10	83.33
23	12	7	18	8	10	55.56
24	13	6	22	7	15	68.18
25	8	6	13	2	11	84.62
MEAN	11.88	6.8	18.52	9.56	8.96	46.03
ST.DV.	6.392	5.252	10.174	7.869	7.413	30.949
MAX	26	24	41	31	31	84.62
MIN	2	1	2	1	-1	-33.33

Table 13. Weighted and un-weighted PAR scores with point and percentage reductions

When comparing the present study results with those of the General Dental Services' survey performed by Richmond in 1990, 76% (19 cases) of the cases fell into Richmond's improved (≥ 30% PAR reduction) category, 0.04% (1 case) was greatly improved (≥ 22 points PAR reduction), and 24% (6 cases) fell into the no difference or became worse category(< 30% PAR reduction). 40% (10 cases) of the samples post-treatment alignment was deemed excellent (PAR of 5) as proposed by Richmond. 32% (8 cases) was deemed acceptable (PAR of 10) alignment and 28% (7 cases) was deemed unacceptable (> PAR of 10) alignment.

The mean change between the overall pre-treatment PAR score and the post-treatment PAR score showed a significant difference (p<.001)(Table 14), suggesting a positive overall treatment effect. The individual components measured within the British weighted PAR score were analyzed using a one-way analysis of the variances. The ANOVA found that the upper and lower labial alignment components showed a statistically significant difference between pre-treatment PAR scores and post-treatment PAR scores (Table 15). The upper labial alignment was significantly improved (p< 0.05) and the lower labial alignment also showed significant improvement (p< 0.05). The overbite change was the only other component that approached significance (p= .066).

Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference Lower	Upper			
Pair 1 TOTAL2 - TOTAL	-8.96	7.413	1.483	-12.02	-5.90	-6.043	24	.000

Table 14. Results of a paired t-test showing significant mean treatment change between pre-treatment PAR score and post-treatment PAR score.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
D_UPPER	Between Groups	47.833	14	3.417	3.361	.030
	Within Groups	10.167	10	1.017		
	Total	58.000	24			
D_LOWER	Between Groups	70.573	14	5.041	5.215	.006
	Within Groups	9.667	10	.967		
	Total	80.240	24			
D_LEFT	Between Groups	31.540	14	2.253	1.669	.210
	Within Groups	13.500	10	1.350		
	Total	45.040	24			
D_RIGHT	Between Groups	33.827	14	2.416	1.318	.336
	Within Groups	18.333	10	1.833		
	Total	52.160	24			
D_OJ	Between Groups	335.760	14	23.983	2.351	.089
	Within Groups	102.000	10	10.200		
	Total	437.760	24			
D_OB	Between Groups	17.093	14	1.221	2.616	.066
	Within Groups	4.667	10	.467		
	Total	21.760	24			
D_MIDLIN	Between Groups	45.333	14	3.238	1.735	.192
	Within Groups	18.667	10	1.867		
	Total	64.000	24			

Table 15. One-way ANOVA comparing PAR components between pre-treatment and post-treatment mean changes. The "D" represents the difference between the pre- and post-treatment.

The mean post-treatment change for the ABO scoring (Table 16) was 32.48 ± 10.44. The maximum post-treatment ABO score was 53 and the minimum score was 17. 28% (7 cases) of the sample finished with acceptable ABO scores. Of the 7 cases finishing with passing ABO scores, 3 began treatment (Table 17) with passing ABO scores. 27% of the mean post treatment ABO score was determined by the occlusal contact score. 15.1% of the mean post treatment ABO score was determined by the Maxillary alignment score, and 13.9% of the mean post-treatment ABO score was determined by the occlusal relationship score.

CASE	ALIGNMENT		MARGINAL RIDGES		BUCCOLING. INCLINATION		ROOT ANGLES	OCCLUSAL CONTACT	OCCLUSAL RELATIONSHIP	OVER-JET	INTER-PROXIMAL CONTACTS	TOTAL
	Max	Mand	Max	Mand	Max	Mand						
1	3	2	2	2	6	6	1	0	18	12	0	52
2	3	3	2	2	0	3	N/A	4	2	1	0	20
3	6	1	1	3	4	0	N/A	6	2	4	0	27
4	4	1	2	2	4	5	2	1	2	0	0	23
5	5	5	2	0	4	3	N/A	3	7	0	0	29
6	10	7	0	3	3	4	0	5	6	0	0	38
7	8	6	4	6	2	4	2	11	6	1	0	50
8	6	2	0	3	6	4	0	14	6	1	0	42
9	5	5	0	1	0	1	0	9	4	2	0	27
10	7	6	1	1	0	2	0	14	18	4	0	53
11	7	2	3	1	2	2	N/A	8	6	5	0	36
12	5	3	1	3	4	2	0	14	0	6	0	38
13	7	2	2	1	5	2	1	9	2	3	0	34
14	1	6	2	0	0	0	0	11	5	0	0	25
15	8	6	1	1	2	1	N/A	15	0	6	0	40
16	2	4	0	0	3	3	N/A	8	1	7	0	28
17	3	8	1	0	2	0	0	8	2	2	0	26
18	7	4	3	2	4	3	N/A	14	4	3	0	44
19	10	4	1	1	2	1	N/A	12	7	2	0	40
20	4	4	0	0	0	4	0	1	2	2	0	17
21	4	3	0	0	2	2	0	8	3	1	0	23
22	1	2	1	0	1	4	0	11	1	0	0	21
23	2	4	1	2	0	2	1	1	5	2	0	20
24	3	2	3	1	0	2	0	18	4	0	0	33
25	2	3	1	0	2	1	3	14	0	0	0	26
MEAN	4.92	3.8	1.36	1.4	2.32	2.44	0.58824	8.76	4.52	2.56	0	32.48
ST.DV.	2.61	1.91	1.11	1.44	1.93	1.5832	0.93934	5.101307	4.619884558	2.89	0	10.441
MAX	10	8	4	6	6	6	3	18	18	12	0	53
MIN	1	1	0	0	0	0	0	0	0	0	0	17

Table 16. Post-treatment ABO scores. Not all cases included a panoramic radiograph with final record as noted by N/A.

CASE	ALIGNMENT		MARGINAL RIDGES		BUCCOLING. INCLINATION		ROOT ANGLES	OCCLUSAL CONTACT	OCCLUSAL RELATIONSHIP	OVER-JET	INTER-PROXIMAL CONTACTS	TOTAL
	Max	Mand	Max	Mand	Max	Mand						
2	7	7	2	3	0	3	N/A	2	2	1	0	27
4	6	4	3	2	4	5	2	1	2	3	0	32
14	3	6	1	1	0	2	0	2	4	4	0	23
20	8	8	0	0	0	4	0	2	0	4	0	26
21	5	4	0	0	2	2	0	1	2	1	0	17
22	5	9	1	0	1	5	0	2	1	0	1	25
23	5	10	1	2	0	2	1	0	6	1	0	28
MEAN	5.57	6.86	1.14	1.14	1	3.286	0.5	1.4285714	2.428571429	2	0.142857	25.43
ST.DV.	1.62	2.34	1.07	1.21	1.528	1.38	0.8367	0.7867958	1.988059595	1.633	0.377964	4.65
MAX	8	10	3	3	4	5	2	2	6	4	1	32
MIN	3	4	0	0	0	2	0	0	0	0	0	17

Table 17. Pre-treatment ABO scores of selected cases finishing with passing ABO scores.

DISCUSSION

This study found that the mean British weighted percentage reduction in PAR score with the Invisalign System was 46.03%. This value is lower than values calculated in previous studies which looked at treatment effectiveness. O'Brien et al[56] looked at 1630 treated orthodontic cases and found the mean reduction in PAR to be 68%. Richmond [57] also found a higher percentage (78%) of PAR reduction among patients treated by Norwegian orthodontic specialists. Historically, removable appliances have shown low improvement when assessed by the PAR index[58]. However, this study shows the treatment effect between the pre-treatment and post-treatment mean reduction in PAR scores to be significant. In addition, over three quarters of the sample fell into the improved category, indicating treatment success.

When considering the treatment effects, we must remember that if the case begins with a PAR score of 22 or less, then it is impossible to finish in Richmond's "greatly improved" category. This applies to 64% (16) of the cases found in this study and, therefore gives the impression that the appliance may be somewhat defective. But, if we look individually at the cases that began treatment with a weighted PAR score in Richmond's acceptable alignment category, 20%(5) of the cases began acceptable and 72%(18) finished with acceptable alignment, further indicating treatment success.

The features which the Invisalign System is most successful and least successful at treating become more apparent when we consider Table15. Both the upper and lower anterior alignment respond well to the Invisalign treatment. This coincides with Boyd's comments about the Invisalign System's ability to tip teeth efficiently. Table 15 also agrees with Boyd's comments about the correction of overbite to be a fairly predictable movement for the Invisalign System, as overbite correction in the study approaches statistical significance. However, it should be noted that the PAR Index is very critical of antero-posterior buccal segment

relations. All teeth from the canine posteriorly are included in this measurement so that most cases will accumulate points here. It is almost impossible to reduce this figure to zero and many of the cases that finish with acceptable or excellent alignment fail to meet the ideal buccal segment standards set by the PAR index. With this being addressed, the Invisalign System showed the least improvement in the posterior buccal segments.

The ABO grading system is more sensitive to occlusal refinement than the PAR Index. By examining Table 16, it becomes apparent that the occlusal contacts make up a large percentage of the total post-treatment score. This corroborates Boyd's findings of a higher frequency of posterior openbites in patients treated with the Invisalign System. Unlike the PAR index, the ABO grading system accrues points with even the slightest opening between occlusal contacts. The ABO grading also includes all erupted teeth in the calculation of the maxillary and mandibular alignment components. As anterior alignment was greatly reduced using the PAR Index, the effect on alignment using the ABO standards appears to be less efficient. The current study noted limited treatment effects on maxillary and mandibular posterior alignment.

Some limitations of the current study include the small sample size. With the Invisalign System being on the market for only a few years, little time has elapsed to establish a large pool of Invisalign treated patients with complete final records. Also, the cases which have finished early are usually the more minor cases, and therefore do not fully test the treatment capabilities of this new system. Furthermore, the PAR index fails to evaluate periodontal health, root resorption, tooth angulations, patient satisfaction, functional occlusion or patient compliance. All of which could be useful in determining treatment effectiveness.

CONCLUSIONS

The introduction of the Invisalign System has opened up some new treatment options for those adult patients unwilling to pursue traditional orthodontic treatment modalities. But other than a few case reports indicating treatment results, little has been documented as to the effectiveness of this new orthodontic appliance. The current study examined the treatment effects of selected cases treated solely with the Invisalign System. The PAR index has been shown to be an easy and reproducible index for assessing treatment success. Furthermore, with the ABO grading criteria, the subtleties of occlusal refinement may be examined. These six points will summarize findings from the current study:

1) The mean percentage of PAR reduction for the sample was 46.03%. This represents a significant treatment change.

2) 76% of the post-treatment cases had percentage reduction in PAR scores that placed them into Richmond's improved category, indicating successful treatment.

3) 72% of the cases had post-treatment PAR scores sufficient to be placed in Richmond's acceptable alignment category further indicating successful treatment.

4) Only the maxillary anterior and the mandibular anterior alignment showed statistically significant improvement with treatment.

5) 28% of the cases passed the ABO scoring criteria. Of these, 43% began treatment with passing ABO scores.

6) The occlusal contact score accounted for 27% of the post-treatment ABO score.

Even though this preliminary data suggests treatment success with the Invisalign System, further follow up needs to be performed due to the small sample size and the relative minor pre-treatment conditions of the sample.

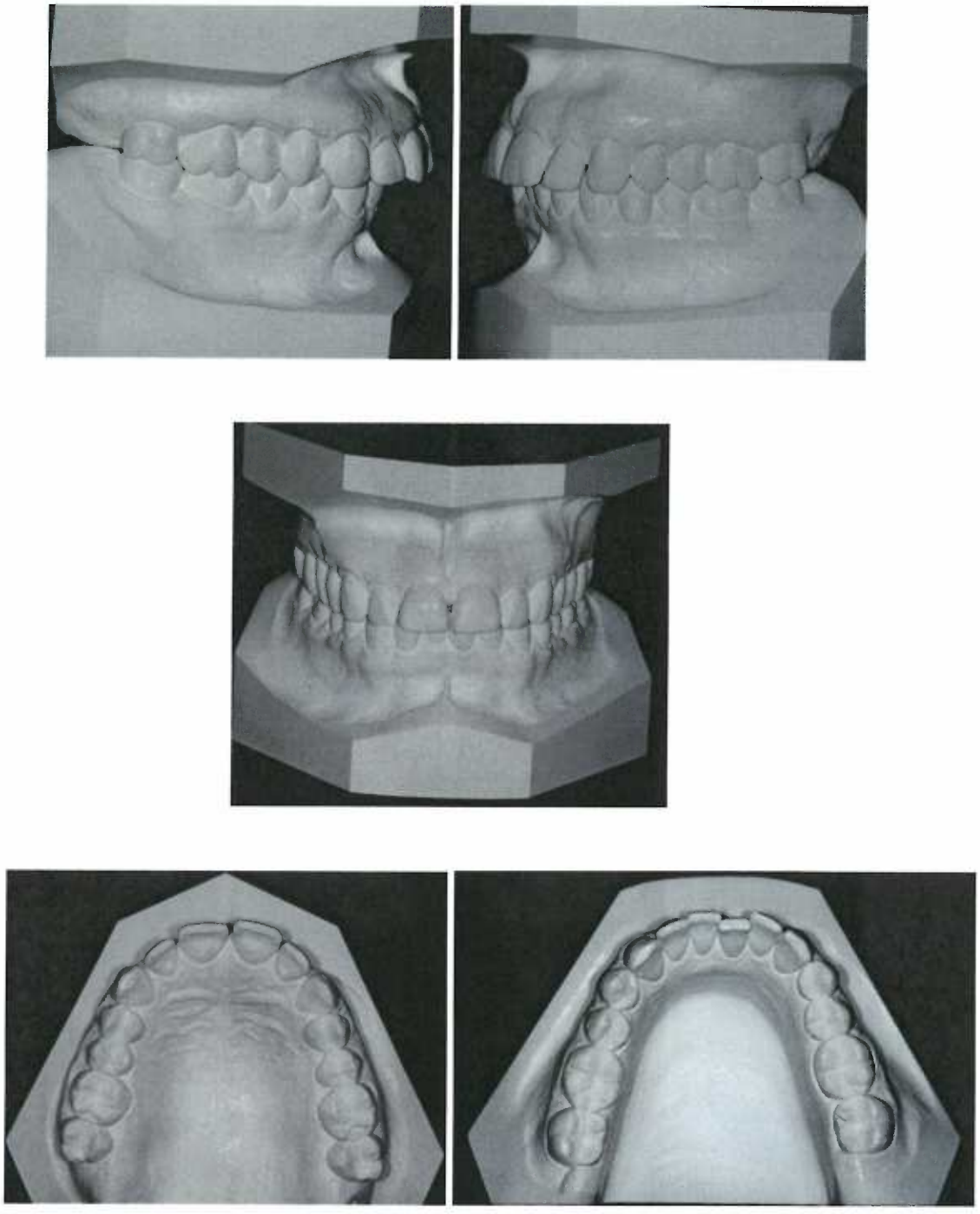

Figure 1. CASE 14 Pre-Treatment Photographs

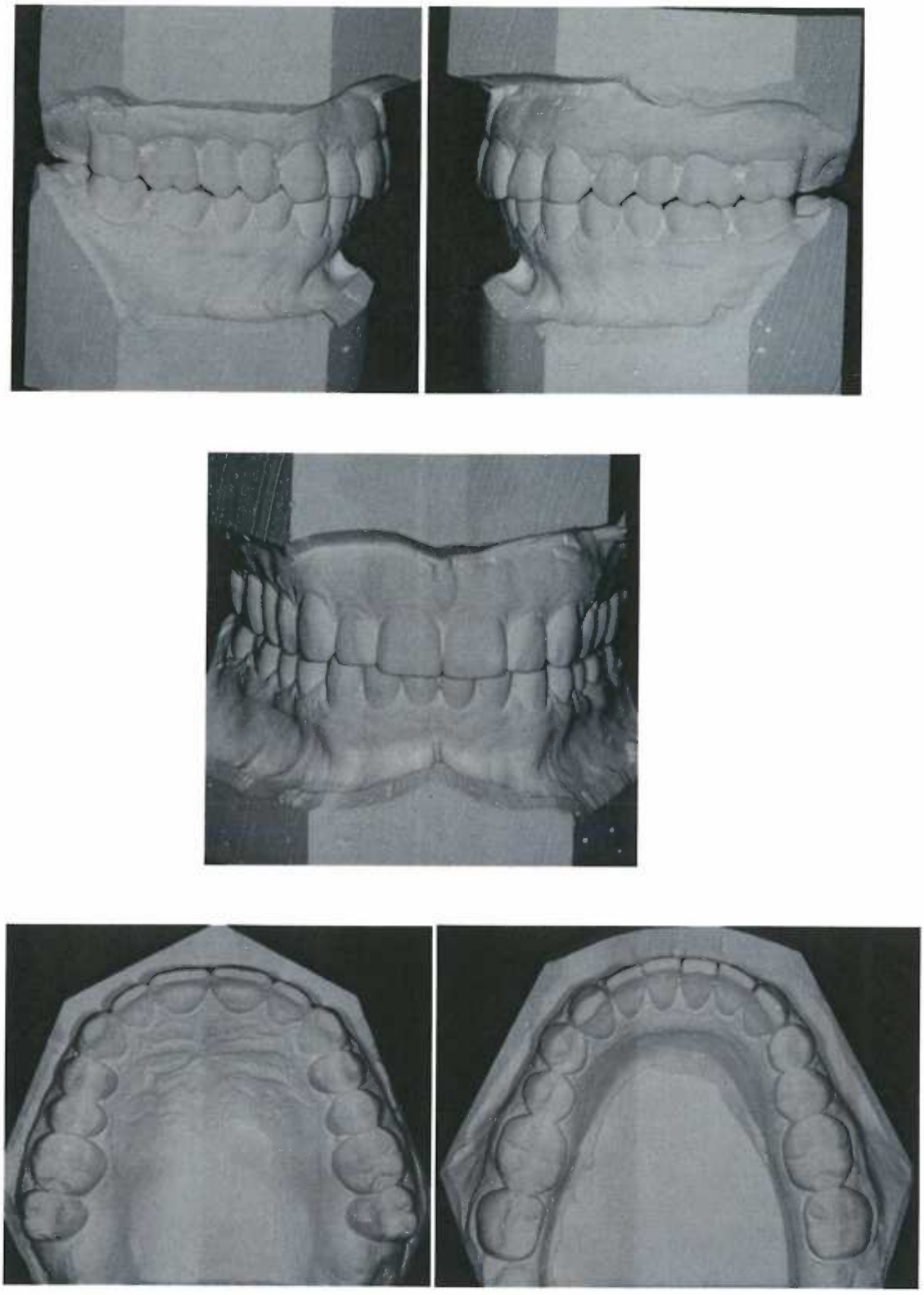

Figure 2. Case 14 post-treatment photos

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