# Orthodontic Outcomes in Class II Correction with Elastics: Clear Aligners Versus Fixed Appliances

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Abstract

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**Abstract**

**Introduction**: Clear aligner therapy is rapidly gaining market share and offers aesthetic and hygienic benefits; however, their efficacy in Class II correction with elastics remains under-researched compared to traditional fixed appliances.

**Specific Aims**: This study compares anteroposterior and vertical dentoalveolar, facial, and skeletal changes between clear aligners and fixed appliances. Differences in treatment efficiency and outcome variations between growing versus non-growing patients were evaluated based on technique.

**Research Design and Methods**: This is a retrospective cohort study involving 132 subjects (64 clear aligner, 68 fixed appliance) categorized into growing and non-growing cohorts based on age. Data collection included lateral cephalometric tracings, 3D digital model analysis, and additional treatment factors such as IPR. Linear regression was used to compare post-treatment variance by adjusting for pre-treatment values. Effect of appliance type on each parameter is represented by the coefficient ß.

**Results**: The analysis revealed no significant difference in treatment time between aligners and fixed appliances (~23–25 months). However, fixed appliances showed significantly more buccal crown torque added to incisors, 9.47º (7.10, 11.8) in adolescents and 8.68° (2.02, 15.3) in adults compared to aligners. Clear aligners demonstrated less vertical change, showing significantly less overbite reduction.

**Conclusions**: Each appliance type offers distinct clinical advantages: clear aligners provide better control of lower incisor torque and vertical dimensions, while fixed appliances may be more effective for deep overbite correction. Skeletal and facial changes were largely similar across both modalities, suggesting outcomes are primarily driven by initial dental and biological factors rather than the appliance type.

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# INTRODUCTION

## INTRODUCTION AND STATEMENT OF THE PROBLEM

Clear aligner therapy has been increasing in popularity in the orthodontic correction of malocclusion due to perceived benefits over traditional fixed appliances. Claims of increased esthetics during treatment, reduced office recall frequency with decreased treatment and chair time, ease of maintaining proper oral hygiene, reduced discomfort, and fewer dietary restrictions provide a compelling argument for clear aligner usage to patients and clinicians.[1,2] Clear aligner market share is projected to increase from US $5.56 billion in 2023 to US $18.63 billion in 2029 with a compounded annual growth rate (CAGR) of 22% according to report published by Daedal Research Group, in part due aggressive marketing strategies.[3] As the implementation of clear aligner treatment is consistently increasing, it is more important to understand its role in the modern practice of orthodontics.

A growing market share represents a greater number of patients starting their orthodontic journey with clear aligner therapy; however, as the boundaries for what clear aligner therapy can achieve are expanded, the possible dentoalveolar movements in comparison to fixed appliances must be defined. In 1945, the use of a post-treatment positioner to achieve final settling and corrections by H.D. Kesling preceded the implementation of thermoplastic materials in conjunction with interproximal reduction to make minor tooth movements.[4] In 1997, Invisalign® introduced the world to the first commercially produced clear aligner therapy as a viable form of orthodontic treatment.[5] Since introduction, countless variations on the clear aligner have been developed, each proposing their own unique advantage. While they were initially developed for minor adjustments, clinicians have since pushed the boundaries of what is achievable by employing clear aligner therapy on more difficult cases. Today, movements previously thought

to be unattainable by clear aligner therapy, such as open bite correction, extraction space closure, and anteroposterior improvement, have been performed by experienced clinicians.[6,7]

Increase in implementation of clear aligner therapy has been propelled by advances in the underlying technology of biomaterials and computer aided design and manufacturing (CAD/CAM).[8] Primarily, the usage of tooth-movement prediction models has given the orthodontic community an optimistic idea of what is clinically feasible to achieve, such as ClinCheck® predicted expansion involving a significantly greater amount bodily movement of teeth than clinically observed.[9] Several published studies have investigated different aspects of effectiveness of clear aligner therapy, evaluating control over root movements, intermaxillary overjet correction, effectiveness at managing long-span diastema closure and arch expansion, but no distinct conclusion has been made specifically addressing dentoalveolar, facial, and skeletal outcomes achieved during Class II correction with elastics as compared to fixed appliances.[10–12]

## List Of Specific Aims

Aim #1: Compare the anteroposterior dentoalveolar, facial, and skeletal changes that occur during Class II correction with elastics between clear aligner therapy and fixed appliances.

Aim #2: Compare the vertical dentoalveolar, facial, and skeletal changes that occur during Class II correction with elastics between clear aligner therapy and fixed appliances.

Aim #3: Identify treatment efficiency (represented by total treatment time) to achieve Class I occlusion, between clear aligner therapy and fixed appliances in Class II correction with elastics.

Aim #4: Investigate treatment outcome differences in growing versus non-growing patients during Class II correction between clear aligner therapy and fixed appliances.

## BACKGROUND AND SIGNIFICANCE

### BACKGROUND, LITERATURE, AND SIGNIFICANCE OF THE PROBLEM

The field of orthodontics has witnessed significant advancements in the last 150 years, particularly in the context of Class II orthodontic correction after the initial introduction of intermaxillary elastics by Henry Baker in the late 1800s.[13] The more traditional approach involving fixed appliances of various designs has been documented to induce primarily dentoalveolar changes that contribute to, or are sequelae of, reaching Class I occlusion.[14,15] In conjunction with class II elastics, these changes include lingual tipping, retrusion, and extrusion of the maxillary incisors, labial tipping and intrusion of mandibular incisors, and mesialization and extrusion of the mandibular molars as found in a systematic review conducted in 2007 by Guilherme Janson, et al.[15] A retrospective study conducted by Combrink, et al. in 2006 determined that this treatment modality induced non-significant changes in SNA of -1.58º and SNB of 0.11º; however, ANB was significantly decreased by an average of 2.09º. Further, it was quantified that a mean overjet reduction of 3.816mm was achieved alongside proclination of the lower incisors with IMPA increasing by 13.717º. Guilherme, et al. additionally concluded that light elastic use (73.7g) was the most common with an average duration of 8.5 months.

Further literature has attempted to characterize dentoalveolar and skeletal changes in Class II correction with other mechanisms through lateral cephalometric analysis throughout history by various clinicians including Byron Tovstein (1955), Raleigh Williams (1968), Anthony Gianelly (1984), Malcolm Meistrell (1986), Birgitta Nelson (1999), and Aslihan Uzel (2007) and their respective teams through elastics in conjunction with edgewise appliances, cervical and high pull headgear, the Begg technique, utility arches, and the reciprocal mini chin cup.[14,16–20] An understanding of these mechanisms has empowered practitioners in effective

treatment planning, outcome prediction, and the selection of appropriate correction methods to attain desired results.

Despite the literature available for fixed appliances, information focusing on Class II correction with clear aligners is largely anecdotal, relying on case studies[21–23] and studies evaluating the predictive reliability of Invisalign ClinCheck outcomes.[8,24–30] Simulated models have also been employed to understand the potential of clear aligners in Class II orthodontic correction, but have limited clinical significance.[31–33]

To bridge the deficiency in knowledge surrounding the efficacy of clear aligners in Class II correction, three studies aimed to address this gap by specifically concentrating on growing adolescents reaching Class I occlusion. The first is a retrospective cohort study conducted by Dianiskova et al. evaluated pre- and post-treatment lateral cephalometric radiographs to evaluate dental and skeletal parameters.[34] Irsheid et al. also evaluated lower incisor position in a similar growing patient population as well; however, they used dental casts for clinical outcome assessment.[35] A third study by Laganà et al. is a randomized control trial with an evaluation method similar to Dianiskova et al., comparing tracings of lateral cephalometric radiographs in growing adolescents.[36] While all studies are well conducted, this approach introduces a potential bias as they focused solely on adolescents which predisposed them to validate results that may not be achievable without accompanied growth. Further, Dianiskova et al. found results that differ from the other two studies, highlighting a significant difference in the lower incisor inclination between the fixed appliance and clear aligner group while the two other studies did not. This leaves clinicians with incomplete information and may lead to dissatisfaction with treatment outcomes or frustration due to an inability to achieve their initially set goals. As such,

there still exists lack of researched-based evidence where both growing and non-growing patients have been evaluated and compared.

To make informed decisions about the use of clear aligner therapy in Class II orthodontic correction, it is imperative to distinguish the dentoalveolar movements and accuracy with which clear aligners can correct Class II malocclusion in comparison to treatment outcomes of fixed appliances. This distinction is crucial for clinicians in tailoring treatment plans to each patient's unique initial presentation. Clear aligners offer several advantages, such as enhanced aesthetics, comfort, and ease of maintenance compared to traditional fixed appliances; however, understanding the limitations and potential challenges associated with clear aligner therapy is equally important to determine in which situations they provide a clinical benefit. Should dentoalveolar changes induced by clear aligners differ from those achieved with fixed appliances, overall treatment efficacy may be impacted.

Addressing this disparity in information requires a comprehensive analysis of clear aligner treatment outcomes across growing and non-growing patient populations. Additionally, direct comparisons of these treatment outcomes to fixed appliances with Class II elastics will shed light on the relative merits and drawbacks of each approach.

The utilization of clear aligners in Class II orthodontic correction represents a promising addition to traditional fixed appliances in an orthodontist’s toolkit. The current knowledge gap and potential biases in existing studies necessitate a more comprehensive and impartial investigation into the efficacy of clear aligners in this specific context. Employing this new information, clinicians would be able to carefully weigh the advantages and limitations of each treatment modality, considering factors such as patient preferences, treatment goals, and the complexity of malocclusion to reach their desired outcomes more efficiently and effectively.

## Purpose of the Study

The purpose of this study is to evaluate differences in the dentoalveolar, facial, and skeletal changes that occur during Class II correction with elastics differ between clear aligner therapy and fixed appliances from pre-treatment ($T_0$) to post-treatment ($T_1$) timepoints.

## Research Questions and Hypotheses

Question 1: Do the dentoalveolar changes that occur in the anteroposterior dimension during Class II correction with elastics differ between clear aligners and fixed appliances?

Null Hypothesis 1.1: There is no difference in retraction/retrusion of maxillary incisors, mesialization of mandibular molars, nor incisal inclination between the treatment modalities of clear aligners and fixed appliances during Class II correction.

Hypothesis 1.1: Clear aligners have less control over root movement and will therefore achieve less retraction/retrusion of maxillary incisors, less mesialization of mandibular molars, and a lower degree of incisal inclination change.[37]

Null Hypothesis 1.2: Full fixed appliances and clear aligner therapy have no anteroposterior dimension difference in achieving Class I occlusion between growing and nongrowing patients.

Hypothesis 1.2: Growing patients have more anteroposterior movement during Class II correction with elastics for both treatment modalities.

Question 2: Do the dentoalveolar changes that occur in the vertical dimension during Class II correction with elastics differ between clear aligners and fixed appliances?

Null Hypothesis 2.1: There is no difference in the extrusion of maxillary incisors and mandibular molars nor the intrusion of mandibular incisors between the treatment modalities of clear aligners and fixed appliances during Class II correction.

Hypothesis 2.1: Clear aligners have greater control of the vertical dimension and therefore show less extrusion of maxillary incisors and mandibular molars and more intrusion of mandibular incisors.[38]

Null Hypothesis 2.2: Full fixed appliances and clear aligner therapy have no vertical dimension difference in achieving Class I occlusion between growing and nongrowing patients.

Hypothesis 2.2: Growing patients have more vertical movement during Class II correction with elastics for both treatment modalities.

Question 3: Are fixed appliances more efficient in achieving Class I occlusion in comparison to clear aligner therapy?

Null Hypothesis 3.1: Full fixed appliances and clear aligner therapy show no difference in treatment time in achieving Class I occlusion when controlled for severity of initial Class II anteroposterior presentation.

Hypothesis 3.1: Full fixed appliances are more efficient in achieving Class I, as measured by time elapsed from pre-treatment ($T_0$) to debond ($T_1$).

Null Hypothesis 3.2: Full fixed appliances and clear aligner therapy have no elapsed time difference in achieving Class I occlusion between growing and nongrowing patients.

Hypothesis 3.2: Growing patients can achieve Class I occlusion in a shorter pre-treatment ($T_0$) to post-treatment ($T_1$) timeframe for both treatment modalities.

## MATERIALS AND METHODS

### AUTHORIZATION

Approval from the Institutional Review Board was obtained from the UW Human Subjects Division prior to conducting this study on December 23rd, 2024 (STUDY00021661). Funding support was provided by the UW Orthodontic Alumni Association.

### RESEARCH DESIGN

This was a retrospective cohort study evaluating the dental positions, skeletal maturation, treatment efficiency, and facial esthetics of patients who undergo orthodontic treatment for Class II malocclusion with fixed appliances or clear aligners exclusively utilizing elastics for anteroposterior correction. Two groups of subjects were identified based on their treatment modality: fixed appliances and clear aligner therapy. The groups were further split into growing and non-growing based on both CVM and age.

### SAMPLE COLLECTION

Subjects were obtained from two private practices and from the University of Washington Graduate Orthodontic Clinic database. To identify Orthodontists who would be willing and able to provide patient cases, a survey was sent out to the Washington State Society of Orthodontics listserv (Appendix A). Those who affirmatively responded to using clear aligners in correcting Class II malocclusion with elastics and took the required pre- and post-treatment records were contacted for collection of records. Patients were filtered by Class II initial malocclusion corrected only with Class II elastics and organized chronologically by finish date, starting with the most recent debonded cases. Sorting by debond date rather than most recent treatment initiation eliminated any bias towards cases that progressed abnormally fast. The average start date for both clear aligners and fixed appliances is in 2020, with aligner

treatment start dates ranging from March, 2015 to September, 2023 and fixed appliances treatment start dates ranging from June, 2016 to January, 2024. Pre-treatment ($T_0$) and post-treatment ($T_1$) lateral cephalograms, 3D digital models, and photographic records of patients who meet the inclusion criteria were de-identified and collected from participating practitioners. Each subject was given a unique, de novo, six-digit identifier to allow for anonymous record keeping and data evaluation. All records were uploaded to Dolphin Imaging 12.0.63 software.

**Provider criteria**:

- An orthodontist who routinely performs orthodontic treatment.
- Has a sufficiently large patient population to allow the practitioner to provide consecutive cases that meet the inclusion criteria.
- Routinely takes cephalometric radiographs before and after treatment.

**Patient inclusion criteria:**

- Underwent Class II correction with clear aligners or fixed appliances
- Class II half cusp, full cusp, and those with a more severe discrepancy
- Class II, division 1 or 2
- Anteroposterior correction included Class II elastics only
- Aligners with buttons or cutouts for elastic usage
- Can include aligner cases that also utilize sequential distalization in conjunction with elastics
- Systems
    - Full fixed appliances: edgewise bracket systems with buccal application
    - Clear aligners: all comprehensive clear aligner brands and manufacturers
- Endpoint/ Treatment Completion: any occlusal relationship at debond

**Patient exclusion criteria:**

- Anteroposterior classifications of Class I or Class III
- Cases treated with functional appliances, Carriere, additional appliances, or TAD usage
- Cases undergoing surgical correction
- Systems
    - Full fixed appliances: Lingual bracket systems, combination fixed appliances and aligner usage
    - Clear aligners: Invisalign First or other mixed dentition systems

- Subjects with extractions (excluding third molars)
- Subjects with congenitally missing teeth
- Subjects with self-reported non-compliance with aligner wear or elastic wear

## Data Collection

Pertinent data documented for analysis and group comparison prior to cephalometric and digital model analysis included patient age at the start of treatment, race, sex, treatment duration from bonding or aligner delivery to debonding, and patient compliance during treatment (tray schedule adhesion and/or elastic usage). Patients who did not meet the criteria, or did not have all necessary data available, were excluded.

The 3D digital models were used to classify the initial molar and canine anteroposterior classification severity along with the amount of arch length deficiency or excess for comparison between the groups. Anteroposterior class severity was based on an inter-arch cusp relationship spectrum. The mesiobuccal cusp of the maxillary first molar was visually divided into vertical fourths and scored in relation to distance along the cusp from the mesiobuccal groove of the mandibular first molar. Categories included ¼ cusp, ½ cusp, ¾ cusp, or full cusp Class II. Inclusion criteria specified that all patients began Class II to some degree. If there was a discrepancy in the molar classification from right to left, a subdivision, the more severe Class II side was recorded. Arch length was measured from the occlusal view of each initial model in both the maxilla and mandible separately. ABO CR scoring dictates evaluation of arch length excess, deficiency, or sufficiency through defining the arch shape and length and measuring the clinical crown structure that can fit into that pre-determined space. This measurement was made from the distal of the right canine to the distal of the left canine. Arch length excess is represented by positive numbers, arch length deficiency is any negative number, and arch length sufficiency was recorded as zero.

A lack of consistent literature around cephalometric classification of division 1 and division 2 patients lead the research team to implement a de novo formula to provide consistent and measurable categories. Utilizing the division 2 defining characteristics of retroclined maxillary incisors and reduced overjet, the data was separated based on a combination of those two parameters after cephalometric tracing. Dolphin imaging software defines average overjet as 3mm and average U1-NA as 22.8° ± 5.7. Therefore, if a patient had an overjet that was less than 3mm and an U1-NA that was less than one standard deviation less than the norm at 17.1°, they were classified as division 2, any combination that was greater than those numbers in either category was considered division 1. Every patient was further evaluated visually by two researchers independently and categorized. These lists were compared and if there existed a disagreement, a third researcher acted as the tie breaker. It can be noted the actual prevalence of Class II malocclusion is difficult to determine on a population level. Different methods of categorizing patients used in various studies show the prevalence of Class II division 1 and division 2 malocclusions varies from 8.6%1 to 33.7% and from 0.6% 1 to 6.7% on a population level, respectively.[39]

Total amount of interproximal reduction (IPR) was gathered and totaled for each arch from distal of the canine to distal of the contralateral canine. In the aligner patients, this was found in the final approved Clinchecks. All previous IPR was listed in red and new IPR for the final round of aligners was added to each of those values. For those patients with fixed appliances, each individual clinical note was evaluated for mention of IPR and totaled as necessary for each arch. The data collected included a general “yes/no” statement indicating if any IPR was completed at all during treatment, and then further quantified the amount performed in each arch.

All lateral cephalometric images were traced in the Dolphin Imaging software by placing the 54 landmark points below. From the tracing analysis, data for the following parameters were collected: Maxillary and mandibular skeletal relations (SNB, SNA, ANB), interincisal relation (overjet, overbite), incisor inclination and protrusion (maxillary incisor to Nasion-A point and palatal plane, mandibular incisor to Nasion-B point and mandibular plane), mandibular inclination in relation to Frankfort Horizontal and Sella-Nasion, and both upper and lower lip relation to esthetic plane.

**Skeletal & Cranial Landmarks (26):**

- Cranial Base: Sella, Clinoidale, Basion, Roof of orbit, Supraorbitale
- Upper Face: PT point, Nasion, Orbitale, Key Ridge, Temporale , Porion
- Maxilla: A Point, Anterior Nasal Spine (ANS), Posterior Nasal Spine (PNS)
- Mandible: B Point, Pogonion, Gnathion, Menton, Gonion, Condylion, Articulare, Ramus Point, Mid Ramus, Sigmoid Notch
- Symphysis: Internal Symphysis (Superior & Inferior)

**Dental Landmarks (14):**

- Posterior Dentition (U6 & L6): U6 Occlusal, Distal U6, Mesial U6, L6 Occlusal, Distal L6, Mesial L6
- Anterior Dentition (U1 & L1): U1 Tip, U1 Root, U1 Labial Gingival Border, U1 Lingual Gingival Border, L1 Tip, L1 Root, L1 Labial Gingival Border, L1 Lingual Gingival Border

**Soft Tissue Landmarks (14):**

- Profile: Soft Tissue Glabella, Soft Tissue Nasion, Bridge of Nose, Tip of Nose, Subnasale, Soft Tissue A-Point, Soft Tissue B-Point
- Lips: Upper Lip, Lower Lip, Stomion superius, Stomion inferius
- Chin: Soft Tissue Pogonion, Soft Tissue Gnathion, Soft Tissue Menton

**Calibration Landmarks (2):**

- Ruler: Ruler point 1, ruler point 2

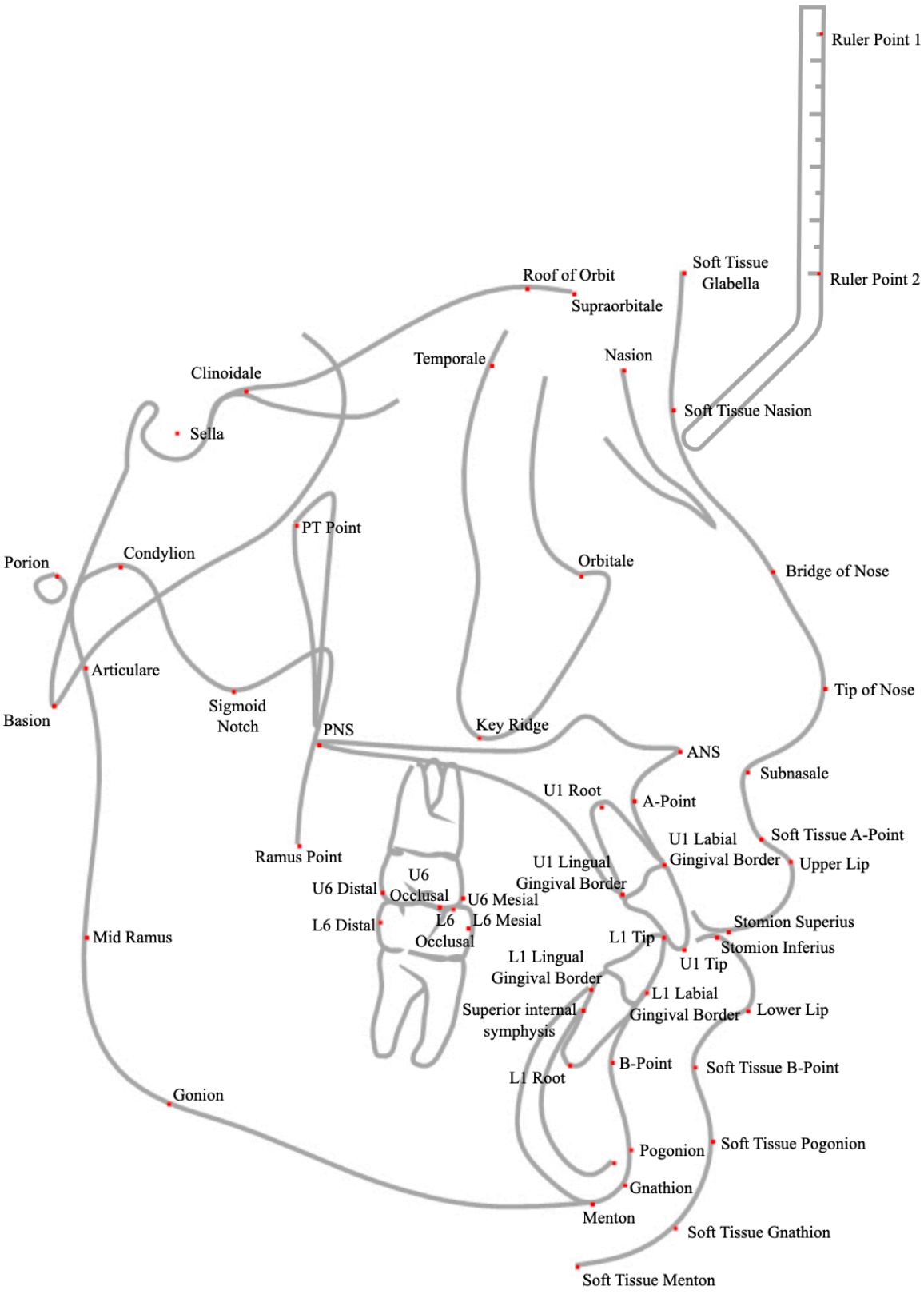


*Figure 1. Cephalometric Tracing Points Diagram*

Along with age, the cervical vertebral maturation (CVM) index on initial lateral cephalometric images was employed to assess growth status of the sampled subjects. Those radiographs where the second (C2), third (C3), and fourth (C4) were visible were assigned a CVM stage (1-6). Stages 1-2 indicate a pre-pubertal stage, 3-4 correlate with a circum-pubertal or growth stage, and 5-6 are associated with post-pubertal, non-growing, or maturation stage. Those images where the CVM was unable to be assessed, primarily due to the use of a lead apron collar, were excluded from this analysis only.

All data was compiled in a secure Microsoft Excel spreadsheet for analysis.

## RELIABILITY

Intra-examiner reliability of lateral cephalometric tracings was assessed through tracing repetition of ten randomly selected subjects with at least a two-week waiting period. Five patients each from fixed appliances and clear aligner groups were identified, placed in a separate Dolphin Imaging patient file, re-traced without knowledge of their modality of treatment, and compared with the original tracing data.

The mean and standard deviation (SD) were computed for each set of measurements. Using these values, the mean of the differences, 95% confidence interval (CI) for the mean difference, the intraclass correlation coefficient (ICC), and 95% CI for the ICC was computed to describe the reliability.[40] Dahlberg's error and the minimum and maximum for the absolute value of the difference between the two measurements was computed to describe the measurement error.[41]

## Sample Size Calculation

The sample size was determined based on an 80% probability that there is a difference between a specific measure between the two groups at a given magnitude of difference. This difference specified in terms of standard deviation units, providing an effect size. To compute the effect sizes observed by Dianiskova et al as a reference, the difference between the two means was divided by the average of the standard deviations. Effect sizes in their study range from 0 to 1/3. However, the study was only powered to detect a bigger effect size of 0.9. .

Sample size was determined to have 80% power to detect an effect size in the desired range of 0.50 to 0.75 based on two-sample t-test and two-sided significance level of 0.05. For an effect size of 0.75 and 80% power, at least 29 subjects were necessary in each group. Table 1 summarizes each sample size requirement at a given effect size.

Table 1. Sample Size per Effect Size

| Effect Size | Sample Size |
|---|---|
| 0.25 | 253 |
| 0.33 | 143 |
| 0.50 | 64 |
| 0.67 | 37 |
| 0.75 | 29 |
| 1.0 | 17 |

## Statistical Analysis

The study employed a variety of statistical analyses to evaluate baseline differences and determine treatment effects. To compare the two treatment groups, Welch's two-sample t-test was used for continuous variables such as age and treatment time, while the chi-squared or Fisher's exact test were used for categorical data such as sex and Angle's classification. The primary analysis utilized linear regression to compare fixed appliance and clear aligner groups at post-treatment, adjusting for baseline values to isolate the relative effect of the appliance type on

24 different cephalometric and dental parameters. The regression analyses were performed separately for growing (adolescent) and non-growing (adult) participants to account for potential effects of growth, specifically in the mandible, on Class II correction. Growing participants were defined as those <18 years-old and non-growing participants were defined as 18 years old or older. For adolescents, additional regression analysis controlled for other confounding variables, including race, sex, and initial arch length discrepancies. There were too few adult participants to adjust for other confounders beyond the baseline values.

According to the American Board of Orthodontics Grading System for Dental Casts and Panoramic Radiographs criteria, deviations of 0.5 mm or greater in the alignment of contact points and marginal ridges result in the deduction of points. A marginal ridge discrepancy of 0.5 mm equates to a crown-tip deviation of 2° for an average-sized molar.[42] Therefore, differences of 0.5 mm or more in the mesial-distal, facial-lingual, and occlusal-gingival directions and differences of 2° or more in tip, torque, and rotation are considered clinically relevant.

## RESULTS

### SAMPLE DEMOGRAPHICS

Pre-treatment patient characteristics are outlined in Table 2. The fixed appliances group consisted of 46 females and 22 males with a mean age of 15.2 ± 5.8 years. The clear aligner group had 49 females and 14 males with a mean age of 16.9 ± 8.7 years. No significant differences were found between groups for sex or age (P= 0.190 and 0.527 respectively). In total, 132 participants were included in this study. For the purposes of identifying patient growth, cervical vertebral maturation index was used to categorize patients as pre-pubertal and peri-pubertal or "growing" and post-pubertal or "nongrowing." Due to frequent use of the thyroid collar during lateral cephalometric radiographs, it was impossible to categorize enough of the sample to draw meaningful conclusions on this metric (Appendix Table A). As such, the sample was divided into growing and non-growing cohorts by age.

**Table 2.** Sample Demographics

| Characteristic | Overall N = 132 | Clear Aligner N = 64 | Fixed Appliance N = 68 | p-value |
|---|---|---|---|---|
| **Age, y** | | | | 0.190[1] |
| Mean (SD) | 16.0 (7.3) | 16.9 (8.7) | 15.2 (5.8) | |
| Min to Max | 10.4, 54.0 | 10.4, 54.0 | 10.6, 41.0 | |
| **Age, y, n (%)** | | | | 0.527[2] |
| <18 | 112 (84.8%) | 53 (82.8%) | 59 (86.8%) | |
| 18+ | 20 (15.2%) | 11 (17.2%) | 9 (13.2%) | |
| **Sex, n (%)** | | | | 0.254[2] |
| Female | 95 (72.0%) | 49 (76.6%) | 46 (67.6%) | |
| Male | 37 (28.0%) | 15 (23.4%) | 22 (32.4%) | |

[1]Welch Two Sample t-test; [2]Pearson's Chi-squared test

## Baseline and Treatment Factors

Validation of the subject's initial dental similarity and additional treatment factors is presented in Tables 3 and 4, respectively. Relevant parameters of initial anteroposterior molar and canine class discrepancy, maxillary and mandibular intra-arch length discrepancy, and Class II division were recorded to evaluate if statistically significant differences exist between the groups before treatment was started. Additional treatment factors and debond characteristics include total amount of interproximal reduction performed in both maxillary and mandibular arches, total treatment time, and molar as well as canine anteroposterior class upon treatment termination.

Initial canine and molar classification was based on the position of the mesiobuccal cusp of the maxillary first molar in relation to the mesiobuccal groove of the mandibular first molar. There was no significant difference in both initial canine classification and initial molar classification between the clear aligner and fixed appliance groups with the majority of patients being 1/2 cusp Class II in both groups (P= 0.792). This holds true in both growing and non-growing patients.

Mandibular and maxillary intra-arch length discrepancies were also evaluated. Arch length excess and deficiency are represented by positive and negative numbers, respectively, and arch length sufficiency was recorded as zero. At initial records, both clear aligner and fixed appliance groups had a comparable amount of maxillary arch length discrepancy at -1.9mm ± 2.5mm and -1.0mm ± 3.1mm respectively; however, the fixed appliance group had a light bias towards less mandibular crowding with -0.7mm ± 2.5mm while the clear aligner group measured in at -1.7mm ± 2.0mm (P=0.013).

The final pre-treatment measurement recorded was Class II division. From the sample collected, there is no significant difference in division 1 or 2 between the clear aligner and fixed appliances groups with 87.5% and 89.7% respectively (P = 0.690). This holds true for both growing and non-growing groups separately; however, it is important to note there were no division 2 patients in the fixed appliance adult cohort and only 4 in the clear aligner group. Overall, the total sample had 88.6% division 1 patients and 11.4% division 2 patients.

**Table 3.** Baseline Dental Similarity

| **Characteristic** | **Overall** N = 132 | **Clear Aligner** N = 64 | **Fixed Appliance** N = 68 | **p-value** |
|---|---|---|---|---|
| **Initial canine classification, n (%)** | | | | 0.854[1] |
| II 1/4 | 38 (28.8%) | 20 (31.3%) | 18 (26.5%) | |
| II 1/2 | 77 (58.3%) | 35 (54.7%) | 42 (61.8%) | |
| II 3/4 | 12 (9.1%) | 6 (9.4%) | 6 (8.8%) | |
| II FC | 5 (3.8%) | 3 (4.7%) | 2 (2.9%) | |
| **Initial molar classification, n (%)** | | | | >0.999[1] |
| II 1/4 | 39 (29.5%) | 19 (29.7%) | 20 (29.4%) | |
| II 1/2 | 75 (56.8%) | 36 (56.3%) | 39 (57.4%) | |
| II 3/4 | 10 (7.6%) | 5 (7.8%) | 5 (7.4%) | |
| II FC | 8 (6.1%) | 4 (6.3%) | 4 (5.9%) | |
| **Maxillary Arch Length** | | | | 0.059[2] |
| Mean (SD) | -1.4 (2.8) | -1.9 (2.5) | -1.0 (3.1) | |
| Min to Max | -7.0, 8.0 | -6.0, 4.0 | -7.0, 8.0 | |
| **Mandible Arch Length** | | | | **0.013[2]** |
| Mean (SD) | -1.2 (2.3) | -1.7 (2.0) | -0.7 (2.5) | |
| Min to Max | -8.0, 7.0 | -5.0, 7.0 | -8.0, 6.0 | |
| **Division, n (%)** | | | | 0.690[3] |
| 1 | 117 (88.6%) | 56 (87.5%) | 61 (89.7%) | |
| 2 | 15 (11.4%) | 8 (12.5%) | 7 (10.3%) | |

[1]Fisher's exact test; [2]Welch Two Sample t-test; [3]Pearson's Chi-squared test

Total amount of interproximal reduction, as noted in Table 4, was evaluated as a “yes/no” value if any was performed at all and further totaled separately for each arch. Overall, 34.1% of patients had IPR at some point during treatment. Separately, 35.9% of the clear aligner group and 32.4% of the fixed appliance group had IPR (P= 0.664). Of the clear aligner patients, 21.9% had maxillary IPR and 25% had mandibular IPR while 13.2% and 23.5% of the fixed appliance

group had maxillary and mandibular IPR respectively. Of the patients that had maxillary IPR >0, the average total maxillary amount of was 0.7mm for clear aligners and 0.9mm for fixed appliances (P= 0.678). Of the patients that had mandibular IPR >0, the average total mandibular amount was 1.5mm for clear aligners and 1.2mm for fixed appliances (P=0.540).

Total treatment time was evaluated for the two appliance groups and was also separated by growth status to mitigate bias. In total, clear aligner treatment time was on average 25.2 ± 9.7 months and fixed appliance treatment time was 23.2 ± 4.2 months with no significant difference between the groups (P = 0.138). This holds true for both non-growing and growing patients. In non-growing patients, younger than 18, average treatment time was 24.7 ± 8.3 months for clear aligners and 23.3 ± 4.2 months for fixed appliances (P = 0.204). Finally, in growing patients, 18 and older, average treatment time was 27.8 ± 14.8 months for clear aligners and 23.0 ± 4.8 months for fixed appliances (P = 0.336).

Anteroposterior class upon termination of treatment was determined in the same way as the initial canine class; however, the values also include Class I and Class III, broken into the same quartered cusp values, as some patients may have been overcorrected or have a Bolton discrepancy that leads to a mismatch between canine and molar class. Here, there was not a significant difference between final canine classification in clear aligner and fixed appliances groups with largest subsection of patients finishing Class I, 51.6% and 47.1% respectively (P = 0.605). There was, however, a significant difference between final molar classification between the two groups, with clear aligners showing more overcorrection of the molar to Class III and fixed appliances showing slight under-correction to ¼ cusp Class II (P = 0.008).

**Table 4.** Additional Treatment Factors and Debond Characteristics

| Characteristic | Overall | Clear Aligner | Fixed Appliance | p-value |
|---|---|---|---|---|
| **Interproximal reduction, n (%)** | N = 132 | N = 64 | N = 68 | 0.664[1] |
| No | 87 (65.9%) | 41 (64.1%) | 46 (67.6%) | |
| Yes | 45 (34.1%) | 23 (35.9%) | 22 (32.4%) | |
| **Maxillary IPR** | N = 23 | N = 14 | N = 9 | 0.678[2] |
| Mean (SD) | 0.8 (0.9) | 0.7 (0.6) | 0.9 (1.3) | |
| Median (IQR) | 0.4 (0.2, 1.3) | 0.5 (0.2, 1.2) | 0.2 (0.2, 1.5) | |
| Min to Max | 0.2, 4.0 | 0.2, 1.9 | 0.2, 4.0 | |
| Skewness | 2 | 0.7 | 1.4 | |
| **Mandible IPR** | N = 32 | N = 16 | N = 16 | 0.540[2] |
| Mean (SD) | 1.3 (1.2) | 1.5 (1.4) | 1.2 (0.9) | |
| Median (IQR) | 1.0 (0.6, 1.5) | 1.2 (0.5, 1.8) | 1.0 (0.7, 1.4) | |
| Min to Max | 0.3, 5.6 | 0.3, 5.6 | 0.3, 4.0 | |
| Skewness | 2 | 1.7 | 1.7 | |
| **Tx time, m** | N = 132 | N = 64 | N = 68 | 0.138[2] |
| Mean (SD) | 24.2 (7.4) | 25.2 (9.7) | 23.2 (4.2) | |
| Min to Max | 9.2, 52.5 | 9.2, 52.5 | 15.6, 36.7 | |
| **Final canine classification, n (%)** | N = 132 | N = 64 | N = 68 | 0.872[3] |
| I | 65 (49.2%) | 33 (51.6%) | 32 (47.1%) | |
| II 1/4 | 61 (46.2%) | 28 (43.8%) | 33 (48.5%) | |
| II 1/2 | 6 (4.5%) | 3 (4.7%) | 3 (4.4%) | |
| **Final molar classification, n (%)** | N = 132 | N = 64 | N = 68 | **0.008[3]** |
| III 1/2 | 2 (1.5%) | 2 (3.1%) | 0 (0.0%) | |
| III 1/4 | 8 (6.1%) | 7 (10.9%) | 1 (1.5%) | |
| I | 84 (63.6%) | 43 (67.2%) | 41 (60.3%) | |
| II 1/4 | 27 (20.5%) | 7 (10.9%) | 20 (29.4%) | |
| II 1/2 | 11 (8.3%) | 5 (7.8%) | 6 (8.8%) | |

[1]Pearson's Chi-squared test; [2]Welch Two Sample t-test; [3]Fisher's exact test

## RELIABILITY

Reliability results are reported in Table B of the appendix. Intra-examiner reliability overall was high with intraclass correlation coefficients (ICC) ranging from 0.81 to 1.00. Measurements of SNB, ANS-Gn, and Lower E-plane had ICC values of 1.00, and the majority of both skeletal and dental values showed high reproducibility. However, those of palatal plane inclination and SGn-FH (deg) were on the lower end of the range of the ICCs of 0.81.

Measurement error, as assessed by Dalhberg's error, was small for most variables, 1.0 or less for both degree and millimetric values. Palatal plane inclination again showed the most variability with maximum absolute difference up to 6.2°. Additionally, a systematic error was identified for Co-ANS as the 95% confidence interval for the mean difference between the repeated measurement (-2.9 to -1.0) did not include zero which suggests a consistent bias between the repeated measurements.

As such, values for palatal plane inclination and Co-ANS can be found in the Results, but they will not be evaluated in the discussion.

### Cephalometric Analysis

To evaluate the cephalometric data, the clear aligner and fixed appliances groups were separated by age to represent growing, younger than 18, and non-growing, 18 and older, cohorts as discussed above. There were 112 adolescent subjects and 20 adult subjects included in the analysis of the pre-treatment and post-treatment cephalometric data. The values calculated included the skeletal metrics of SNA, SNB, ANB, and mandibular inclination (to Frankfort horizontal as FH-MeGo and to cranial base SN-MnP); dental values of overjet, overbite, U1-NA (degrees and distance in mm), U1-Palatal Plane, L1-NB (degrees and distance in mm), L1-MP, Inter-incisal angle (U1-L1); and facial parameters of upper and lower lip to E-plane, chin projection (Pog-NB), and lower face height (ANS-GN).

As retrospective studies often do, the groups' baseline cephalometric data differs significantly across several categories, as seen in Appendix Table C. SNA, SNB, Overbite, U1-NA (mm and degrees), U1-Palatal plane, L1-MP (mm and degrees), upper lip to E-plane, and lower lip to E-plane all have variance that equate to a p-value $<0.05$. As such, linear regression analysis adjusting for baseline was performed to determine meaningful changes.

All linear regression models evaluate the mean change between fixed appliances and clear aligners and adjust for each respective initial value. These data for adolescents and adults can be found in Table 5 and 6 respectively alongside the coefficient ß, number of observations, and $R^2$. Adolescent subjects' data was also further adjusted for treatment time, sex, race, initial canine class, initial molar class, division, maxillary arch length discrepancy, and mandibular arch length discrepancy to determine any correlation with other treatment parameters and potential confounding variables. Of these data, the most clinically relevant was those values related to Division 2 patients; all these values can be found in Appendix Table F. Due to a small number of adult subjects, it was not possible to run the regression analysis adjusting for multiple variables; the regression estimates became unstable and unreliable as variables were added. As such, this regression was only run without additional adjustments.

Results of the linear regression in Table 5 show that every value has a statically significant correlation with the initial value in adolescent patients except overjet; those that have additional significance with appliance type include SNB, ANB, SN-MnP, Overbite, U1-NA (degrees and mm), U1-Palatal Plane, L1-MP, L1-NB (degrees and mm), interincisal angle. Table 6 similarly shows significance in relation to the initial value for all categories in adult patients except overjet, L1-MP, and interincisal angle. Of those values, appliance type has the most effect on L1-MP and interincisal angle.

The coefficient ß values showing relative effect are highlighted in the forest plot of Figure 1. For each category, the central point represents the coefficient ß that indicates the magnitude and direction of the relative effect between the two appliance types. Positive effect values indicate fixed appliances significantly increase the measurement of a specific category in comparison to clear aligners while negative effect values indicate a reduction in the measurement

of that category relative to clear aligners. The arms extending from each side represent the 95% confidence interval; if either of the arms cross zero on the y-axis, that indicates there is no significant difference between the two appliance types. Interincisal angle is the most reduced by fixed appliances with an effect of -12.4° due to significant proclination of both upper (U1-NA) and lower incisors (L1-MP) by 7.02° and 9.47° respectively. The same holds true for adults as seen in Figure 2 and Table 6 with the statistically significant primary driver of interincisal angle reduction of -12.4° being lower incisal angle (L1-MP) at 8.68°.

Additional values for Wits appraisal, maxillary unit length (Co-ANS), mandibular unit length (Co-Pog), Harvold analysis (CoPog)-(CoANS), Y-Axis Downs (SGn-FH), and palatal plane inclination were measured as part of each cephalometric tracing; however, were not included in analysis due to the scope of the study. These data can be found in Tables D and E of the appendix for adolescents and adults respectively.

**Table 5** <18 Linear Regression: Cephalometric Outcomes Between Fixed Appliances and Clear Aligners

| Group | Coefficient ß | 95% CI | p-value | R2 |
|---|---|---|---|---|
| **SNA (º)** | | | | 0.827 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 0.11 | -0.53, 0.75 | 0.734 | |
| Initial Value | 0.99 | 0.90, 1.09 | <0.001 | |
| **SNB (º)** | | | | 0.831 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 0.73 | 0.13, 1.33 | **0.018** | |
| Initial Value | 0.99 | 0.89, 1.08 | <0.001 | |
| **ANB (º)** | | | | 0.715 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | -0.65 | -1.12, -0.18 | **0.007** | |
| Initial Value | 1.04 | 0.91, 1.17 | <0.001 | |
| **FH-MeGo (º)** (Mandibular Inclination to Frankfort Horizontal) | | | | 0.807 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | -0.36 | -1.39, 0.67 | 0.488 | |
| Initial Value | 0.98 | 0.89, 1.08 | <0.001 | |
| **SN-MnP (º)** (Mandibular Inclination to Cranial Base) | | | | 0.896 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | -0.78 | -1.54, -0.02 | **0.045** | |
| Initial Value | 0.99 | 0.92, 1.06 | <0.001 | |
| **Overjet (mm)** | | | | 0.025 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 0.02 | -0.25, 0.29 | 0.873 | |
| Initial Value | 0.07 | -0.01, 0.14 | 0.082 | |
| **Overbite (mm)** | | | | 0.237 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | -0.82 | -1.09, -0.55 | **<0.001** | |
| Initial Value | 0.12 | 0.05, 0.19 | <0.001 | |
| **U1-NA (º)** | | | | 0.295 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 7.02 | 4.86, 9.18 | **<0.001** | |
| Initial Value | 0.24 | 0.12, 0.37 | <0.001 | |
| **U1-NA (mm)** | | | | 0.297 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 1.73 | 0.91, 2.55 | **<0.001** | |
| Initial Value | 0.41 | 0.26, 0.56 | <0.001 | |
| **U1-Palatal (º)** | | | | 0.246 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 5.76 | 3.53, 7.98 | **<0.001** | |
| Initial Value | 0.25 | 0.13, 0.38 | <0.001 | |
| **L1-MP (º)** | | | | 0.461 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 9.47 | 7.10, 11.8 | **<0.001** | |
| Initial Value | 0.54 | 0.34, 0.74 | <0.001 | |
| **L1-NB (º)** | | | | 0.316 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 7.02 | 4.91, 9.13 | <0.001 | |
| Initial Value | 0.38 | 0.21, 0.54 | **<0.001** | |
| **L1-NB (mm)** | | | | 0.568 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 1.29 | 0.72, 1.86 | **<0.001** | |
| Initial Value | 0.64 | 0.52, 0.77 | <0.001 | |
| **U1-L1 (º)** (Interincisal Angle) | | | | 0.414 |

**Table 5** <18 Linear Regression: Cephalometric Outcomes Between Fixed Appliances and Clear Aligners

| Group | Coefficient ß | 95% CI | p-value | R2 |
|---|---|---|---|---|
| Clear Aligners | - | - | - | |
| Fixed Appliances | -12.4 | -15.1, -9.73 | **<0.001** | |
| Initial Value | 0.2 | 0.07, 0.32 | 0.002 | |
| **Upper lip to E-Plane (mm)** | | | | 0.68 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 0.27 | -0.38, 0.92 | 0.411 | |
| Initial Value | 0.85 | 0.73, 0.98 | <0.001 | |
| **Lower lip to E-Plane (mm)** | | | | 0.648 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 0.56 | -0.18, 1.30 | 0.135 | |
| Initial Value | 0.81 | 0.67, 0.96 | <0.001 | |
| **ANS-Gn (mm)** (Lower Face Height) | | | | 0.45 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | -0.33 | -2.11, 1.44 | 0.712 | |
| Initial Value | 0.71 | 0.18, 1.24 | 0.009 | |
| **Pog-NB (mm)** (Chin Projection) | | | | 0.895 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 0.19 | -0.04, 0.41 | 0.106 | |
| Initial Value | 0.99 | 0.90, 1.08 | <0.001 | |

Abbreviation: CI = Confidence Interval

**Table 6** 18+ Linear Regression: Cephalometric Outcomes between Fixed Appliances and Clear Aligners

| Group | Coefficient ß | 95% CI | p-value | R2 |
|---|---|---|---|---|
| **SNA (º)** | | | | 0.621 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | -0.11 | -2.55, 2.32 | 0.924 | |
| Initial Value | 0.94 | 0.55, 1.33 | <0.001 | |
| **SNB (º)** | | | | 0.754 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 0.12 | -1.91, 2.15 | 0.905 | |
| Initial Value | 1.05 | 0.80, 1.30 | <0.001 | |
| **ANB (º)** | | | | 0.849 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | -0.25 | -1.39, 0.89 | 0.649 | |
| Initial Value | 1.03 | 0.75, 1.30 | <0.001 | |
| **FH-MeGo (º)** (Mandibular Inclination to Frankfort Horizontal) | | | | 0.936 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 2.09 | 0.29, 3.89 | **0.025** | |
| Initial Value | 0.97 | 0.81, 1.13 | <0.001 | |
| **SN-MnP (º)** (Mandibular Inclination to Cranial Base) | | | | 0.822 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 0.3 | -2.54, 3.14 | 0.825 | |
| Initial Value | 1.02 | 0.81, 1.23 | **<0.**001 | |
| **Overjet (mm)** | | | | 0.301 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | -0.32 | -0.91, 0.27 | 0.272 | |
| Initial Value | 0.16 | -0.04, 0.37 | 0.110 | |
| **Overbite (mm)** | | | | 0.436 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | -1.39 | -2.41, -0.37 | **0.011** | |
| Initial Value | 0.32 | 0.04, 0.59 | 0.028 | |
| **U1-NA (º)** | | | | 0.197 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 2.39 | -2.02, 6.80 | 0.269 | |
| Initial Value | 0.19 | 0.02, 0.35 | 0.028 | |
| **U1-NA (mm)** | | | | 0.688 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 0.75 | -0.79, 2.30 | 0.320 | |
| Initial Value | 0.46 | 0.28, 0.65 | <0.001 | |
| **U1-Palatal (º)** | | | | 0.399 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 5.25 | 1.50, 9.00 | **0.009** | |
| Initial Value | 0.27 | 0.08, 0.45 | 0.008 | |
| **L1-MP (º)** | | | | 0.451 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 8.68 | 2.02, 15.3 | **0.014** | |
| Initial Value | 0.3 | -0.22, 0.82 | 0.237 | |
| **L1-NB (º)** | | | | 0.417 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 7.32 | 0.36, 14.3 | **0.040** | |
| Initial Value | 0.45 | -0.08, 0.97 | 0.090 | |
| **L1-NB (mm)** | | | | 0.573 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 1.15 | -1.01, 3.31 | 0.276 | |
| Initial Value | 0.62 | 0.26, 0.98 | 0.002 | |
| **U1-L1 (º)** (Interincisal Angle) | | | | 0.338 |

**Table 6** 18+ Linear Regression: Cephalometric Outcomes between Fixed Appliances and Clear Aligners

| Group | Coefficient ß | 95% CI | p-value | R2 |
|---|---|---|---|---|
| Clear Aligners | - | - | - | |
| Fixed Appliances | -9.26 | -17.6, -0.95 | **0.031** | |
| Initial Value | 0.09 | -0.20, 0.39 | 0.522 | |
| **Upper lip to E-Plane (mm)** | | | | 0.87 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 0.58 | -0.72, 1.88 | 0.359 | |
| Initial Value | 0.79 | 0.60, 0.99 | <0.001 | |
| **Lower lip to E-Plane (mm)** | | | | 0.565 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 0.39 | -2.69, 3.47 | 0.790 | |
| Initial Value | 0.81 | 0.52, 1.10 | <0.001 | |
| **ANS-Gn (mm)** (Lower Face Height) | | | | 0.962 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 0.32 | -0.80, 1.44 | 0.557 | |
| Initial Value | 1.02 | 0.84, 1.19 | <0.001 | |
| **Pog-NB (mm)** (Chin Projection) | | | | 0.988 |
| Clear Aligners | - | - | - | |
| Fixed Appliances | 0.02 | -0.24, 0.28 | 0.883 | |
| Initial Value | 1.01 | 0.94, 1.08 | <0.001 | |

Abbreviation: CI = Confidence Interval

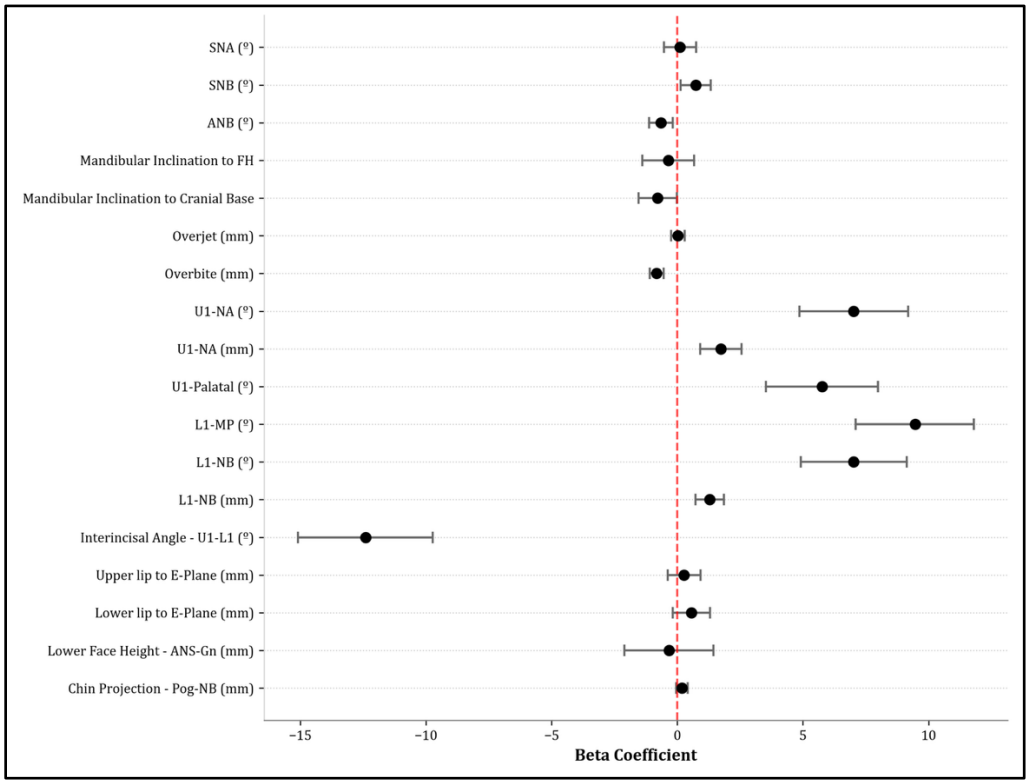


***Figure 2*** *Relative effect of fixed appliances in comparison to clear aligners : <18 years*

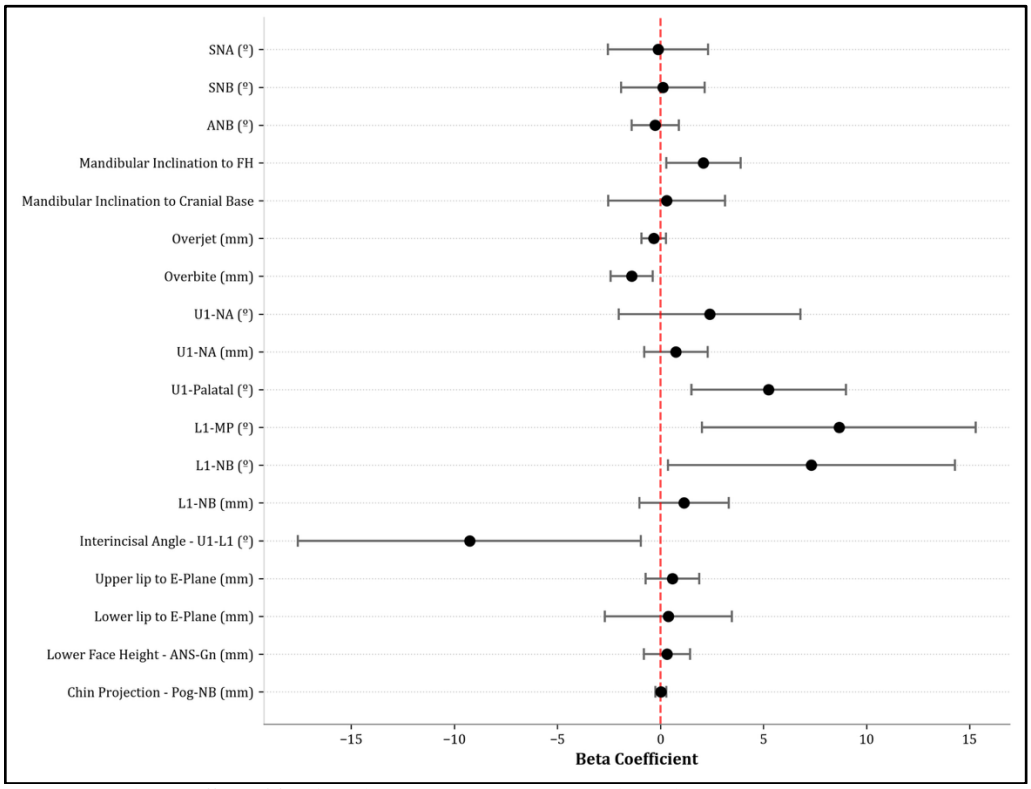


***Figure 3*** *Relative effect of fixed appliances in comparison to clear aligners: 18+ years*

## DISCUSSION

### PRIMARY ANALYSIS

To elucidate any potential differences in the dentoalveolar, facial, and skeletal changes that occur during Class II correction with elastics between clear aligner therapy and fixed appliances, 132 subjects pre- and post-treatment data was collected and evaluated. The study sample is the largest of its kind, has an unparalleled review of both growing and non-growing patients, and provides results that reaffirm and refute various aspects previous literature. While clear aligners and fixed appliances can each achieve Class I occlusal relationships using elastics alone, this study reveals that a significant clinical difference exists across numerous dental parameters, particularly regarding the position of the incisors, in both adolescents and adults. For a practitioner to achieve orthodontic outcomes that mirror treatment goals, the following evaluation of incisor angulation, vertical control, skeletal effects, and treatment efficiency should be considered.

Based on the linear regression, there exists a clinically significant difference in the way that lower incisor angulation is affected between clear aligners and fixed appliances. The angle between lower central incisors and the mandibular plane in the adolescent subjects fixed appliances was 9.47° higher in comparison to the clear aligner group. This value far exceeds what was previously determined to be clinically relevant and highlights a distinction in how the anteroposterior dimension is held in each of the appliances. Though further research is needed to define causation, it can be hypothesized that the slop, or a wires inability to fill a bracket slot in its entirety may contribute to this loss observed of control. As practitioners may want to take advantage of growth and initial adherence to elastic schedules at the beginning of treatment, elastic forces dump lower incisors forward without the control a full-size wire provides. Once the

lower incisors have lost maintenance of initial torque, it may be a challenge to regain this root movement while maintaining the Class II correction. This is in direct opposition to what can be observed in clear aligners as the plastic rigidity is the same from start to debond. Regardless of when along the treatment timeline a practitioner decides to employ elastics, the dentition is held by the same relative forces. These findings are similar to the results of the randomized clinical trial conducted by Laganà et al. in 2025. They state that "the use of Class II elastics in aligner group showed a better control of the lower incisors' inclination, compared to the multibracket fixed appliances group"; however, paradoxically, their results show that the measured differences were non-significant.[36]

In practice, this suggests that patients who have thin gingival biotypes or pre-existing proclination may benefit from clear aligner treatment that offers way to achieve Class II correction while avoiding potential dehiscence or gingival recession.

A divergence between treatment outcomes can be seen further in the linear regression for adolescent patients adjusted for all various treatment parameters. This evaluation routinely showed division 2 patients having significantly different outcomes across multiple cephalometric measures in comparison to division 1. They had more proclined incisors at the end of treatment by 4.41° ($P = 0.020$) and a lower mandibular plane angle than their division 1 counterparts by -1.63° ($P = 0.010$). Each of these changes is digestible in the context that division 2 patients more often present with retroclined incisors that do procline significantly during treatment and low mandibular plane angles that are not clinically affected by treatment but rather influenced to a greater degree by biologic growth potential.

One aspect of treatment to consider when deciding on which Class II mechanics to employ is elastics' side effects in the vertical dimension of mandibular molar and maxillary

canine extrusion, subsequent overbite decrease, and downward and backward rotation of the mandible particularly in non-growing, adult populations.[43] A patient that presents with a high or normal mandibular plane angle may benefit from treatment that can hold the vertical dimension and minimize the extrusive side effects elastics may cause. Results from this study suggest that the in comparison to the clear aligners, in both adolescent and adult groups, the fixed appliances saw overbite decrease significantly by -0.82mm and -1.29mm respectively.

This divergence in treatment outcomes could be attributed to two sources. First, fixed appliances tend to have an extrusive effect on the molars, leading to a decrease in overbite due to the wedge effect. Second, clear aligners have been theorized to produce a bite-block effect that stems from plastic material covering the occlusal surfaces acting as a vertical stop, preventing excess molar extrusion and reducing overbite reduction. Though literature suggests this effect is transient, with posterior occlusal contacts significantly increasing through natural settling after treatment and moving to nighttime wear, the ability to hold molar position when running Class II elastics is paramount to preventing unwanted vertical changes.[44]

An additional aim of this study was to evaluate not only the dental changes, but also any skeletal and facial changes that differ between the groups. In relation to the vertical dimension, and in agreement with previous literature, adult populations appeared to have a significant change in the mandibular plane angle in relation to Frankfort Horizontal with increase of 2.09°. This highlights that in adult patients, using fixed appliances and Class II elastics has a dental effect that clinically manifests as a change in the mandibular plane and cannot be masked by growth as seen in the lack of significance in the adolescent group. Apart from this finding, all other skeletal values remain below the threshold for clinical relevance. The most significant predictor of final position of these skeletal measures was their initial values, meaning that

regardless of appliance, the patient grew or not as was predetermined by their biology. This mirrors conclusions drawn by Dianiskova et al. indicating that while statically significant growth may occur, the clinical manifestation of Class II correction is dental.[34]

Facial changes between clear aligners and fixed appliances similarly showed no differences in any of the metrics evaluated. Upper and lower lips to E-plane, lower face height, and chin projection were all affected in a similar manner regardless of growth status or appliance type. Looking deeper into any association to facial characteristics with initial presentation for adolescent patients, there appears to be a significant correlation between both maxillary crowding and spacing with upper and lower lip flattening and mandibular crowing and spacing with upper and lower lip protrusion. Given both spacing and crowding categories are correlated with the same changes, it can be concluded that overall fixed appliances tend to protrude the lower lip and retract the upper lip more, by about a millimeter each, in relation to clear aligners in the event there is any arch length discrepancy present at the start of treatment.

The final aim of this study was to determine efficiency of the appliances. The results reveal no statistically significant difference in average treatment time between clear aligners and fixed appliances in both adolescents (25.2 months and 23.2 months respectively) and adults (24.7 months and 23.3 months respectively). These relative efficiencies held regardless of growth status. This provides clinicians with the insight to remove treatment time as a factor when determining what appliance to use and focus on the dental effects that most benefit their patients' goals.

Given our findings, it is important to remember that neither system can be considered superior to the other. Flaring lower incisors may be beneficial when a maxillary excess anterior Bolton discrepancy is present and flared lower incisors may help to maintain desired posterior

intercuspation while achieving ideal overjet. Similarly, clear aligners may be more suited for a patient that presents with a shallow overbite to hold the vertical dimension while fixed appliances can potentially perform more reliable deep overbite correction. Each patient's treatment is individual and needs to account for all factors, and the clinician should use their best judgement to achieve the goals set by themselves and the patient together.

## LIMITATIONS

The study was designed to include many practitioners to avoid biases such as clinician experience and case selection; however, uncontrollable factors exist that include differing levels of built in "overcorrection" in the treatment simulation software, various tray change schedules, differing elastic protocols, and the quality of lateral cephalometric images taken at each office. Additionally, although the study design incorporated landmark identification calibration, the variance in isolating structures in lateral cephalometric radiographs, namely Anterior Nasal Spine (ANS), A-point, and condylion (Co), is unavoidable.

Despite the large sample size, only a fraction of them were considered non-growing or adults. Age as a proxy for growth status is not completely reliable, and a different measure, such as cervical vertebral maturation (CVM) could have provided a more literature-based way to separate the groups. Studies that continue to explore this topic may benefit from larger adult sample sizes or utilizing lateral cephalometric radiographs where having a thyroid collar on the patient during exposure is less common.

Further research with CBCT data to identify absolute changes more accurately in dentition with reproducible, stable landmarks would provide additional insight not feasible at this time. Matching intraoral scans based on palatal rugae to identify changes in the dentition may introduce error in the absence of pre- and post- CBCT data and it was therefore decided to use

individual intra-arch pre- and post-treatment measurements rather than rely on inter-model superimposition.

## CONCLUSION

Based on the comprehensive analysis of 132 subjects, this study demonstrates that while both clear aligners and fixed appliances can be effective for achieving anteroposterior change using elastics, they produce distinct dentoalveolar outcomes.

### KEY FINDINGS

- **Incisor Control:** Clear aligners provide significantly better control over lower incisor inclination compared to fixed appliances, which showed a increased proclination (coefficient ß = 9.47° in adolescents and 8.68° in adults).
- **Vertical Dimension**: Clear aligners demonstrated less vertical change, potentially due to a bite-block effect on the posterior dentition resulting in significantly less overbite reduction than fixed appliances.
- **Treatment Efficiency**: No statistically significant difference was found in total treatment time between the two modalities, with both averaging approximately 23 to 25 months regardless of growth status.
- **Skeletal and Facial Impact**: Skeletal changes and facial aesthetic outcomes (such as lip projection and chin position) were largely similar between groups, indicating that these factors are primarily governed by the patient's initial presentation and biology rather than the appliance used.

### CLINICAL IMPLICATIONS

Practitioners should select appliances based on specific patient needs using their knowledge of dental side effects. Clear aligners are suited for patients requiring strict torque and vertical control, whereas fixed appliances remain a powerful tool for deep overbite

correction. Ultimately, the choice of modality should be a tailored decision that aligns the mechanical strengths of the appliance with the individual's unique orthodontic goals.

## APPENDIX

**Table A** Cervical Vertibral Maturation (CVM) Index

| Characteristic | Overall N = 132 | Clear Aligner N = 64 | Fixed Appliance N = 68 | p-value |
|---|---|---|---|---|
| **CVM, n (%)** | | | | 0.0411 |
| 2 | 17 (16.3%) | 4 (7.4%) | 13 (26.0%) | |
| 3 | 21 (20.2%) | 10 (18.5%) | 11 (22.0%) | |
| 4 | 48 (46.2%) | 27 (50.0%) | 21 (42.0%) | |
| 5 | 16 (15.4%) | 11 (20.4%) | 5 (10.0%) | |
| 6 | 2 (1.9%) | 2 (3.7%) | 0 (0.0%) | |
| Missing | 28 | 10 | 18 | |
| **CVM, n (%)** | | | | 0.0582 |
| 2-4 | 86 (82.7%) | 41 (75.9%) | 45 (90.0%) | |
| 5-6 | 18 (17.3%) | 13 (24.1%) | 5 (10.0%) | |
| Missing | 28 | 10 | 18 | |

[1]Fisher's exact test; [2]Pearson's Chi-squared test

**Table B** Inter-Examiner Reliability

| Measure | 1st Mean (SD) | 2nd Mean (SD) | Diff. (SD) [95% CI)] | ICC (95% CI) | D. Error (Min, Max) |
|---|---|---|---|---|---|
| SNA (deg) | 79.7 (4.0) | 80.0 (3.8) | -0.3 (1.5) [-1.4, 0.7] | 0.93 (0.76, 0.98) | 1.0 (0.0, 4.2) |
| SNB (deg) | 75.5 (3.7) | 75.5 (3.6) | 0.0 (0.4) [-0.2, 0.3] | 1.00 (0.98, 1.00) | 0.2 (0.0, 0.6) |
| ANB (deg) | 4.2 (2.9) | 4.6 (2.3) | -0.3 (1.4) [-1.3, 0.6] | 0.87 (0.58, 0.96) | 0.9 (0.0, 4.0) |
| Wits | 1.0 (3.3) | 1.2 (2.6) | -0.2 (1.4) [-1.2, 0.7] | 0.90 (0.67, 0.97) | 0.9 (0.0, 3.9) |
| Co-ANS | 84.5 (4.4) | 86.5 (4.3) | -1.9 (1.4) [-2.9, -1.0] | 0.86 (0.56, 0.96) | 1.7 (0.2, 4.0) |
| Co-Pog | 105.8 (5.6) | 107.0 (4.9) | -1.2 (1.9) [-2.5, 0.1] | 0.92 (0.73, 0.98) | 1.5 (0.0, 4.9) |
| CoPog-CoANS | 21.3 (6.0) | 20.6 (5.0) | 0.8 (1.8) [-0.5, 2.0] | 0.94 (0.81, 0.99) | 1.3 (0.2, 3.7) |
| U1-L1 (deg) | 126.7 (13.2) | 126.2 (12.7) | 0.5 (2.2) [-1.0, 2.1] | 0.99 (0.95, 1.00) | 1.5 (0.2, 5.0) |
| Overjet | 3.8 (1.7) | 4.0 (1.6) | -0.1 (0.3) [-0.4, 0.1] | 0.98 (0.93, 1.00) | 0.2 (0.0, 0.7) |
| Overbite | 3.3 (1.6) | 3.4 (1.6) | -0.1 (0.5) [-0.4, 0.3] | 0.95 (0.83, 0.99) | 0.3 (0.0, 1.1) |
| U1-NA (deg) | 21.0 (6.7) | 21.3 (6.4) | -0.3 (1.8) [-1.6, 1.0] | 0.96 (0.87, 0.99) | 1.2 (0.1, 3.9) |
| U1-NA | 3.8 (3.1) | 3.6 (2.7) | 0.2 (0.6) [-0.3, 0.6] | 0.98 (0.92, 0.99) | 0.4 (0.1, 1.7) |
| U1-PP (deg) | 110.9 (8.8) | 111.6 (9.1) | -0.6 (1.3) [-1.5, 0.3] | 0.99 (0.96, 1.00) | 1.0 (0.1, 2.8) |
| L1-MP | 99.6 (12.9) | 99.4 (12.9) | 0.2 (1.4) [-0.8, 1.2] | 0.99 (0.98, 1.00) | 1.0 (0.4, 2.2) |
| L1-NB (deg) | 28.0 (10.7) | 27.8 (10.1) | 0.3 (1.4) [-0.8, 1.3] | 0.99 (0.97, 1.00) | 1.0 (0.3, 2.2) |
| L1-NB | 6.1 (2.9) | 5.8 (3.1) | 0.3 (0.4) [0.0, 0.5] | 0.99 (0.96, 1.00) | 0.3 (0.1, 0.8) |
| FH-Me-Go (deg) | 22.1 (4.2) | 21.4 (5.4) | 0.6 (2.2) [-0.9, 2.2] | 0.90 (0.67, 0.97) | 1.5 (0.0, 6.0) |
| SN/MnP (deg) | 33.0 (6.5) | 32.9 (6.3) | 0.0 (1.1) [-0.8, 0.8] | 0.99 (0.95, 1.00) | 0.7 (0.1, 2.5) |
| SGn-FH (deg) | 59.6 (2.4) | 59.0 (3.9) | 0.5 (2.0) [-0.9, 2.0] | 0.81 (0.43, 0.95) | 1.4 (0.2, 5.9) |
| ANS-Gn | 64.0 (5.3) | 64.1 (5.4) | 0.0 (0.3) [-0.3, 0.2] | 1.00 (0.99, 1.00) | 0.2 (0.1, 0.8) |
| Palatal Plane | 0.7 (3.5) | 1.2 (3.8) | -0.5 (2.3) [-2.1, 1.2] | 0.81 (0.43, 0.95) | 1.6 (0.3, 6.2) |
| Pog-NB | 2.4 (1.9) | 2.3 (1.5) | 0.0 (0.5) [-0.4, 0.4] | 0.96 (0.84, 0.99) | 0.4 (0.0, 1.1) |
| Upper E-plane | -4.1 (2.9) | -3.9 (2.8) | -0.2 (0.3) [-0.4, 0.0] | 0.99 (0.98, 1.00) | 0.2 (0.1, 0.6) |
| Lower E-plane | -1.0 (3.5) | -1.1 (3.6) | 0.0 (0.2) [-0.1, 0.2] | 1.00 (0.99, 1.00) | 0.2 (0.0, 0.4) |

Diff: difference between means; ICC: interclass correlation coefficient; D. Error: Dahlberg's Error formula.

**Table C** Baseline Characteristic Differences between Clear Aligners and Fixed Appliances

| Variable | Fixed Appliance N = 59 | Clear Aligner N = 53 | Difference | 95% CI | p-value[1] |
|---|---|---|---|---|---|
| **SNA, deg** | | | -1.5 | -2.8, -0.18 | **0.026** |
| Mean (SD) | 80.40 (3.69) | 81.89 (3.31) | | | |
| Min to Max | 73.40, 86.70 | 74.40, 87.80 | | | |
| **SNB, deg** | | | -1.8 | -3.1, -0.51 | **0.006** |
| Mean (SD) | 76.04 (3.31) | 77.82 (3.46) | | | |
| Min to Max | 69.70, 83.80 | 69.50, 83.90 | | | |
| **ANB, deg** | | | 0.30 | -0.41, 1.0 | 0.400 |
| Mean (SD) | 4.36 (1.99) | 4.06 (1.80) | | | |
| Min to Max | 0.10, 8.10 | -0.30, 7.50 | | | |
| **Overjet, mm** | | | -0.16 | -0.81, 0.48 | 0.622 |
| Mean (SD) | 4.54 (1.69) | 4.70 (1.74) | | | |
| Min to Max | 1.60, 10.70 | 1.90, 9.70 | | | |
| **Overbite, mm** | | | 1.3 | 0.65, 2.0 | **<0.001** |
| Mean (SD) | 4.77 (1.98) | 3.47 (1.48) | | | |
| Min to Max | -0.80, 10.90 | -0.30, 7.10 | | | |
| **U1-NA, deg** | | | -8.1 | -12, -4.1 | **<0.001** |
| Mean (SD) | 15.98 (10.79) | 24.07 (10.44) | | | |
| Min to Max | -7.40, 40.70 | -1.70, 43.20 | | | |
| **U1-NA, mm** | | | -2.2 | -3.5, -1.0 | **<0.001** |
| Mean (SD) | 2.68 (3.33) | 4.92 (3.20) | | | |
| Min to Max | -4.60, 9.60 | -2.70, 10.40 | | | |
| **U1 - Palatal plane, deg** | | | -8.6 | -13, -4.7 | **<0.001** |
| Mean (SD) | 105.42 (10.00) | 114.05 (10.98) | | | |
| Min to Max | 84.70, 126.60 | 86.30, 137.50 | | | |
| **L1 - MP, deg** | | | -1.2 | -3.8, 1.3 | 0.349 |
| Mean (SD) | 94.53 (6.91) | 95.74 (6.78) | | | |
| Min to Max | 75.50, 108.60 | 79.70, 109.60 | | | |
| **L1 - NB, deg** | | | -4.6 | -7.1, -2.1 | **<0.001** |
| Mean (SD) | 21.99 (6.81) | 26.59 (6.73) | | | |
| Min to Max | -0.10, 37.00 | 11.50, 37.60 | | | |
| **L1 NB, mm** | | | -1.9 | -2.9, -0.85 | **<0.001** |
| Mean (SD) | 4.18 (2.48) | 6.06 (2.97) | | | |
| Min to Max | -2.50, 9.50 | -0.10, 14.10 | | | |
| **FH - Me-Go, deg** | | | -1.3 | -3.2, 0.70 | 0.207 |
| Mean (SD) | 22.30 (5.11) | 23.56 (5.31) | | | |
| Min to Max | 9.70, 32.60 | 12.90, 32.40 | | | |
| **SN/MnP, deg** | | | -1.7 | -3.8, 0.38 | 0.108 |
| Mean (SD) | 31.44 (5.12) | 33.15 (5.97) | | | |
| Min to Max | 19.40, 42.40 | 21.90, 44.10 | | | |
| **Upper lip to E-plane, mm** | | | -1.5 | -2.5, -0.54 | **0.003** |
| Mean (SD) | -2.95 (2.51) | -1.41 (2.70) | | | |
| Min to Max | -7.80, 3.10 | -6.50, 4.40 | | | |
| Missing | 1 | 2 | | | |

**Table C** Baseline Characteristic Differences between Clear Aligners and Fixed Appliances

| **Variable** | **Fixed Appliance** N = 59 | **Clear Aligner** N = 53 | **Difference** | **95% CI** | **p-value[1]** |
|---|---|---|---|---|---|
| **Lower lip to E-plane, mm** | | | -1.9 | -3.1, -0.82 | **<0.001** |
| Mean (SD) | -1.43 (2.42) | 0.51 (3.34) | | | |
| Min to Max | -7.20, 4.00 | -5.40, 6.30 | | | |
| Missing | 1 | 2 | | | |

[1]Two-sample t-test; Abbreviation: CI = Confidence Interval

**Table D** <18 Linear Regression: Cephalometric Outcomes Between Fixed Appliances and Clear Aligners Additional Variables

| Group | Coefficient ß | 95% CI | p-value | No. Obs. | R2 |
|---|---|---|---|---|---|
| **Wits (mm)** | | | | 112 | 0.437 |
| Clear Aligners | - | - | - | | |
| Fixed Appliances | -0.27 | -0.94, 0.40 | 0.427 | | |
| Initial Value | 0.69 | 0.56, 0.82 | <0.001 | | |
| **Co-ANS (mm)** | | | | 112 | 0.252 |
| Clear Aligners | - | - | - | | |
| Fixed Appliances | 0.52 | -1.90, 2.94 | 0.671 | | |
| Initial Value | 0.64 | 0.21, 1.08 | 0.004 | | |
| **Co-Pog (mm)** | | | | 112 | 0.259 |
| Clear Aligners | - | - | - | | |
| Fixed Appliances | -0.05 | -2.42, 2.32 | 0.968 | | |
| Initial Value | 0.63 | -0.05, 1.31 | 0.069 | | |
| **Harvold Analysis - CoPog-CoANS (º)** | | | | 112 | 0.732 |
| Clear Aligners | - | - | - | | |
| Fixed Appliances | 0.17 | -0.67, 1.02 | 0.684 | | |
| Initial Value | 0.94 | 0.71, 1.17 | <0.001 | | |
| **Y-Axis Downs - SGn-FH (º)** | | | | 112 | 0.73 |
| Clear Aligners | - | - | - | | |
| Fixed Appliances | -0.19 | -1.03, 0.64 | 0.650 | | |
| Initial Value | 0.9 | 0.78, 1.01 | <0.001 | | |
| **Palatal Plane Inclination (º)** | | | | 111 | 0.706 |
| Clear Aligners | - | - | - | | |
| Fixed Appliances | 0.41 | -0.39, 1.20 | 0.313 | | |
| Initial Value | 0.91 | 0.80, 1.01 | <0.001 | | |

Abbreviation: CI = Confidence Interval

**Table E** 18+ Linear Regression: Cephalometric Outcomes Between Fixed Appliances and Clear Aligners Additional Variables

| Group | Coefficient ß | 95% CI | p-value | No. Obs. | R2 |
|---|---|---|---|---|---|
| **Wits (mm)** | | | | 20 | 0.12 |
| Clear Aligners | - | - | - | | |
| Fixed Appliances | -0.29 | -2.30, 1.73 | 0.768 | | |
| Initial Value | 0.37 | -0.05, 0.79 | 0.078 | | |
| **Co-ANS (mm)** | | | | 20 | 0.55 |
| Clear Aligners | - | - | - | | |
| Fixed Appliances | 0.34 | -2.68, 3.35 | 0.817 | | |
| Initial Value | 0.8 | 0.52, 1.08 | <0.001 | | |
| **Co-Pog (mm)** | | | | 20 | 0.743 |
| Clear Aligners | - | - | - | | |
| Fixed Appliances | -1.01 | -3.77, 1.76 | 0.452 | | |
| Initial Value | 0.87 | 0.62, 1.12 | <0.001 | | |
| **Harvold Analysis - CoPog-CoANS (º)** | | | | 20 | 0.836 |
| Clear Aligners | - | - | - | | |
| Fixed Appliances | -0.82 | -2.64, 1.01 | 0.359 | | |
| Initial Value | 1.01 | 0.72, 1.30 | <0.001 | | |
| **Y-Axis Downs - SGn-FH (º)** | | | | 20 | 0.919 |
| Clear Aligners | - | - | - | | |
| Fixed Appliances | 1.77 | 0.25, 3.29 | **0.025** | | |
| Initial Value | 0.95 | 0.81, 1.09 | <0.001 | | |
| **Palatal Plane Inclination (º)** | | | | 20 | 0.897 |
| Clear Aligners | - | - | - | | |
| Fixed Appliances | -2.47 | -3.92, -1.02 | **0.002** | | |
| Initial Value | 0.88 | 0.68, 1.08 | <0.001 | | |

Abbreviation: CI = Confidence Interval

**Table F** <18 Linear Regression: Division 2 Cephalometric Outcomes Relative to Division 1 Adjusted for Initial

| Cephalometric Measurement | Coefficient ß | 95% CI | p-value |
|---|---|---|---|
| SNA (deg) | -0.66 | -1.87, 0.55 | 0.280 |
| SNB (deg) | -0.17 | -1.58, 1.24 | 0.812 |
| ANB (deg) | -0.52 | -1.52, 0.48 | 0.306 |
| Overjet (mm) | -0.05 | -0.50, 0.41 | 0.837 |
| Overbite (mm) | -0.02 | -0.48, 0.44 | 0.924 |
| U1-NA (deg) | 4.74 | -0.46, 9.93 | 0.074 |
| U1-NA (mm) | 1.53 | -0.22, 3.28 | 0.086 |
| U1 - Palatal Plane (deg) | 4.01 | -2.63, 10.6 | 0.234 |
| L1 - MP (deg) | 4.41 | 0.69, 8.12 | **0.020** |
| L1 - NB (deg) | 2.46 | -1.08, 6.00 | 0.172 |
| L1 - NB (mm) | 0.81 | 0.07, 1.55 | **0.033** |
| FH - Me-Go (deg) | -1.63 | -2.85, -0.40 | **0.010** |
| SN/MnP (deg) | -0.49 | -2.32, 1.35 | 0.600 |
| Upper Lip to E-plane (mm) | -0.91 | -1.85, 0.04 | 0.060 |
| Lower Lip to E-plane (mm) | 0.29 | -0.81, 1.40 | 0.599 |
| Wits Appraisal (mm) | -0.17 | -1.58, 1.23 | 0.809 |
| Co-ANS (mm) | 1.22 | -2.35, 4.78 | 0.500 |
| Co-Pog (mm) | 0.89 | -2.29, 4.06 | 0.581 |
| CoPog - CoANS (mm) | 0.15 | -1.55, 1.85 | 0.863 |
| U1-L1 (deg) | -5.34 | -11.5, 0.79 | 0.087 |
| SGn-FH (deg) | -1.12 | -2.22, -0.02 | **0.045** |
| ANS-Gn (mm) | 0.15 | -3.49, 3.78 | 0.936 |
| Palatal Plane (deg) | 0.37 | -1.27, 2.02 | 0.654 |
| Pog-NB (mm) | 0.11 | -0.40, 0.62 | 0.663 |

Abbreviation: CI = Confidence Interval

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