Treatment Outcomes and Stability in Extraction vs. Non-Extraction Adult Anterior Open Bite Patients

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A thesis

submitted in partial fulfillment of the

requirements for the degree of

Master of Science in Dentistry

University of Washington

2022

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Program Authorized to Offer Degree:

Orthodontics

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Abstract

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Introduction: Anterior open bite (AOB) correction is difficult to achieve and more difficult to maintain. Some orthodontists utilize extractions to assist in bite closure. This study aims to explore whether extractions in adult patients with AOB lead to improved treatment outcomes and better long-term stability.

Methods: The pre- and post-treatment records of adult orthodontic patients with AOB were previously obtained through the National Dental Practice-Based Research Network (National Dental PBRN) as part of a larger study. These patients were treated with fixed appliances only. The total sample was divided into extraction and non-extraction groups. Frontal intraoral photographs were obtained at a long-term follow up timepoint for some of the patients. The

Photographic Openbite Severity Index (POSI) was used to assess treatment success and stability. Skeletal, dental and soft tissue treatment outcomes were evaluated using cephalometric analysis.

Results: Pre- and post-treatment records were collected for 115 patients. Among this sample, 33 patients were treated with extractions and 82 were treated without extractions. Pre-treatment differences included a younger extraction group with more crowding and less history of previous orthodontic treatment. Orthodontists had similar success in achieving positive overbite of both central incisors when treating with (97%) or without extractions (92%). No clinically significant differences in skeletal outcomes were observed. The extraction group exhibited more lingual tipping and posterior movement of maxillary and mandibular incisors and less extrusion of mandibular incisors. These dental changes were paired with increased nasolabial angle and lip retraction. The sample size at the long term follow up was not sufficient to draw a significant conclusion regarding stability.

Conclusions: In these adult patients, the rate of successful open bite closure was similar, with or without extractions. The extraction group displayed more retraction and lingual tipping of incisors, as well as increased retraction of soft tissues. Based on a limited sample, all patients in the extraction group had a stable result while 90% of patients in the non-extraction group maintained successful AOB correction at a one-year follow up.

Acknowledgements

I would like to extend my greatest thanks my family and friends for their unwavering support. I would also like to thank the University of Washington Department of Orthodontics and Alumni Association for the opportunity to participate in this project. Thank you to my research committee, Geoffrey Greenlee, Greg Huang and Brian Leroux for their help and guidance.

INTRODUCTION

Anterior Open Bite (AOB) is a dental condition in which patients are unable to obtain vertical overlap of their incisors while occluding on posterior teeth. The prevalence of AOB reported in the literature is variable. The National Health and Nutrition Examination Survey (NHANES) III reports the AOB prevalence in the United States to be approximately 3.5%.[1] The majority of these cases are categorized as mild, with a negative overbite in the range of 0 to -2 millimeters. However, some open bites can be -10 mm or more, and etiologic factors may include dental discrepancies, skeletal discrepancies, oral habits such as thumb-sucking or a tongue thrust, airway obstruction, and condylar dysplasia.[2,3] Some functional challenges associated with this occlusion include difficulty with eating and speech, and esthetics can be compromised in severe cases.

Orthodontists employ many varying approaches to treat this challenging occlusion. Most times, practitioners are successful in achieving positive overbite regardless of treatment modality. Todoki and colleagues reported that positive vertical overlap was achieved for all four incisors in 84% of adult patients with AOB.[4] It is commonly thought that extractions can assist in the orthodontic correction of AOB. The removal of teeth is believed to have two potential benefits, the "wedge effect" in which posterior teeth move anteriorly, causing the first point of tooth contact further away from the mandible's axis of closure [5], and the drawbridge effect, in which incisors are retracted and rotated occlusally increasing vertical overlap of the incisors.[6]

Perhaps more difficult than correcting AOB, is maintaining this correction. Currently, there is limited information on predicting which openbite cases will have significant relapse.[7] The success of both surgical and non-surgical treatment is estimated to be greater than 75%, but this must be considered cautiously due to the lack of high-quality evidence.[8] Some exploration into these treatment modalities in adolescents has provided support to the notion that extraction treatment is more stable than non-extraction treatment in AOB patients.[6] However, this conclusion has been contradicted by others, who found no significant difference in stability.[9,10]

Current literature specifically exploring the outcomes of extraction and non-extraction treatment of AOB in adults is limited. The existing research has primarily investigated children and adolescents, as this is considered by many to be the ideal time to treat AOB. The National Dental Practice-Based Research Network (PBRN) Anterior Openbite Study was a multicenter, prospective cohort study exploring treatment recommendations, outcomes and stability in adults with AOB.[11,12] This study explores a subset of this larger sample to evaluate the impact of extractions on treatment outcomes and stability in patients treated only with fixed appliances.

MATERIALS AND METHODS.

Orthodontists treating adults with AOB were previously recruited through the National Dental Practice-based Research Network (National Dental PBRN) as part of a larger study. Details regarding the practitioners, methods, and findings have previously been published.[4,11, 12] Included patients were a subset of a larger group recruited for the study.

Patients:

Inclusion criteria for patients:

- At least 18 years of age
- Diagnosed with AOB that is defined as one or more incisors that do not have vertical overlap with teeth in the opposing arch. The remaining incisors may have minimal incisor overlap, but none can contact teeth in the opposing arch. This is determined by the practitioner's examination of the patient's initial cephalogram, intraoral photographs and/or initial plaster or digital casts.
- Treatment was completed with fixed appliances only
- Must have pre and post-treatment cephalograms or frontal intraoral photographs. A cephalogram created from a cone-beam CT scan is acceptable.
- Patients were identified by practitioners as having at least mild crowding in at least one arch
- To be included as an extraction patient, at least one incisor, canine, or premolar was extracted for the current round of orthodontic treatment

Exclusion criteria for patients:

- Patients treated with aligners, temporary anchorage devices, or orthognathic surgery
- Patients with clefts or craniofacial syndromes
- Patients without pre-treatment and post-treatment records
- Patients with non-diagnostic pre-intervention and/or end-of-treatment radiographs or frontal intraoral photographs

- Patients who have significant physical, mental or medical conditions that would affect treatment compliance, cooperation and outcome, as determined by the practitioner

Patients were placed in the extraction group if extraction of at least one incisor, canine or premolar was performed as part of this round of orthodontic treatment. Molar extractions were not performed on any of the patients. All included patients had mild to severe crowding in at least one dental arch. Crowding was reported by practitioners as mild (1-3mm), moderate (4-6mm) or severe (>6mm). If crowding scores differed for the maxillary and mandibular arches, patients were categorized by the arch with more significant crowding. According to a power calculation a sample size of 36 in each group would be required to detect a 1mm difference in overbite correction between two independent groups with a standard deviation of 1.5mm.

Data was collected from October 2016 to December 2017. In an effort to avoid selection bias, practitioners were asked to enroll all eligible patients. A maximum of fifteen patients were used for each provider. If more than fifteen patients were eligible, the patients were sequentially selected according to treatment start date.

Pre-treatment (T1) questionnaires were completed by patients and practitioners. Information regarding the amount of pre-treatment crowding, the method of treatment provided, and patient characteristics were included in the doctor's questionnaire. Study questionnaires can be found at http://nationaldentalpbrn.org/anterior-openbite-malocclusions-in-adults-recommendations-treatment-and-stability.php. Cephalograms and intraoral photographs were also obtained at this time point.

At the completion of treatment (T2) cephalograms and intraoral photographs were collected. Dolphin imaging software (version 11.0; Dolphin Imaging and Management Solutions, Chatsworth, Calif) was used for landmark identification on pre-treatment (T1) and post-treatment (T2) cephalograms (Figure 1 and Table 2). An automated custom analysis was created to generate measurements (Table 4). Skeletal and dental cephalometric landmarks and measurements were identified and measured as part of a previous study. Magnification calibration protocol and inter- and intra-rater reliability testing was also reported previously.[5] Soft tissue landmarks (Figure 4) were traced by a single examiner. Reliability testing was not done for cephalometric soft tissue landmarks.

For some patients, frontal intraoral photographs were submitted at least one-year after treatment completion (T3). T1, T2 and T3 open bite severity was assessed using the Photographic Openbite Severity Index (POSI) (Figure 4). This system was developed to categorize the severity of the open bite pre and post-treatment.[11] The seven categories are described below:

0. All four incisors exhibit vertical overlap (No Anterior Open Bite)
1. 1 or 2 maxillary lateral incisors without vertical overlap (but both maxillary central incisors have overlap)
2. 1 maxillary central incisor without vertical overlap (the other maxillary central has vertical overlap
3. Two maxillary central incisors without vertical overlap (at least one maxillary lateral has vertical overlap)
4. All four maxillary incisors without vertical overlap

5. All anterior teeth without overlap (canine to canine)
6. Category 5 plus at least one premolar without vertical overlap

POSI scores were previously determined by two examiners and intra and inter-rater reliability testing was completed.[5] For this study, treatment success was defined as a POSI score of 0 or 1. This means a successful treatment includes vertical overlap at both central incisors.

DATA ANALYSIS

Patient demographics

Pre-treatment demographics were evaluated to determine baseline differences between the two treatment groups. Baseline pre-treatment variables were adjusted for with a linear regression analysis. Pre-treatment patient demographics can be viewed in Table 1.

Treatment success

For this study, treatment success was defined as a POSI score of 0 or 1. Additionally, treatment success was assessed using cephalometric overbite. Both measurements assess positive vertical overlap at the central incisors.

Treatment outcomes

Means for all cephalometric outcomes were calculated at T1 and T2 (Table 6). A multivariate linear regression analysis was performed for each outcome variable to adjust for the influence of age, gender, previous treatment, previous extraction, and moderate to severe crowding.

Stability

Stability was evaluated for patients that achieved treatment success at the conclusion of treatment (POSI= 0 or 1). T2 and T3 POSI scores were compared and a Fischer's exact test was used to determine statistical significance.

Multivariate Linear Regression Analysis

A multivariate linear regression analysis was performed to adjust for pre-treatment age, gender, previous treatment, previous extractions, and crowding. This analysis was also used to assess the impact of extractions on cephalometric treatment outcomes after adjustment for explanitory variables.

RESULTS

115 patients qualified for this study. All patients contributed to the data at T1 and T2, while a reduced number also had data at the final timepoint. This sample was divided into an extraction group (n=33) and a non-extraction group (n=82). 66 patients (11 from the extraction group and 55 from the non-extraction group) had intra-oral photos at least one year after treatment completion to assess long-term stability.

Patient Demographics

At enrollment, the mean age of the patient sample was 33.2 years (sd=12 years; range = 18 to 67.1). The extraction group had greater numbers of young adult patients with 60.6% (n=20) of patients between the ages of 18 and 30 and an average age of 29.6 years (sd=10.3 years). Patients in the non-extraction group were more evenly distributed amongst all age groups with 64.6%

(n=53) of patients between the ages of 21 to 40. The average age of the non-extraction group was 37.7 years (sd=12.4 years). The majority of patients in both groups were female (Non-Ex= 81.9%, Ext=84.8%). 18.2% (n=6) of patients in the extraction group and 37.3% (n=31) of patients in the non-extraction group reported previous orthodontic treatment. Nine (10.8%) patients in the non-extraction group had extractions as part of a previous round of orthodontic treatment.

Pre-Treatment (T1)

More patients in the extraction group had severe crowding (24.2%, n=8) than in the non-extraction group (8.4%, n=7). Conversely, the non-extraction group had a higher percentage of patients with mild crowding (37%, n=44.6) than the extraction group (30.3%, n=10). Pre-treatment cephalometric measurements were largely similar between the two groups (Table 6). One exception is the upper and lower lips, which were more protrusive in the extraction group.

All patients had a POSI score >0 prior to treatment (T1). The most common initial POSI score for both groups was 4—33.7% (n=9) of the non-extraction group and 27% (n=10) of the extraction group. POSI scores for all timepoints can be viewed in Table 5.

Post-Treatment (T2)

Following the completion of treatment (T2), 93.1% (n=107) of patients had a successful treatment outcome, defined as POSI score of 0 or 1. In the extraction group, 97% (n=32) of patients had a POSI score of 0 or 1 at T2. Similarly, 91.5% (n=75) of patients in the non-extraction group had a POSI score of 0 or 1 at T2. Eight patients did not achieve treatment

success, one of which was in the extraction group and seven of which were in the non-extraction group. Of these eight patients, POSI score worsened from T1 to T2 for one patient from the non-extraction group. Openbite correction was also assessed using cephalolmetric overbite. 75 (91%) patients in the non-extraction group and 30 (91%) patients in the extraction group had overbite greater than 0 at the completion of treatment.

In addition to cephalometric analysis, a linear regression analysis was performed to assess the influence of pre-treatment factors on all cephalometric outcomes. These pre-treatment factors included age, gender, previous treatment, previous extractions and crowding. This regression analysis also assessed the effect extractions had on each cephalometric outcome when compared to non-extraction patients after adjustment for these variables. Results of this analysis can be found in Table 7 and Appendix Table 1. Post-treatment overbite was not influenced by any other pre-treatment variable after adjustment, including extractions.

Post-treatment, ANB, mandibular plane angle and lower facial height were largely unchanged and unaffected by any pre-treatment variables or treatment group according to the multivariate linear regression analysis. SNA and SNB were smaller in the extraction group. This difference reached statistical significance but was less than one degree on average. Previous treatment showed a similar influence on SNA, SNB and OB.

For most dental measurements there were significant differences between treatment groups at the end of treatment. However, this does not include overbite and maxillary incisor vertical position, which did not have statistically significant differences between groups at the end of treatment.

Maxillary and mandibular incisors both saw greater reduction in proclination for the extraction group. For maxillary incisors this change was 10.6 degrees on average and for mandibular incisors average change was 8.1 degrees. In contrast the non-extraction group average proclination reduction was 2.6 degrees for the maxilla and 2.1 degrees for the mandible. For lower incisors this change was also influenced by the amount of crowding, with more crowded patients seeing less reduction or an increase in proclination on average. The extraction group also demonstrated a greater reduction in millimetric incisor protrusion. Maxillary incisors in the non-extraction group saw minimal posterior movement while the average retraction in the extraction group was 4mm. For lower incisors, the non-extraction group saw an average increase in protrusion of 0.5mm while the extraction group had an average decrease in protrusion of 2.2mm. Millimetric protrusion was also influenced by the amount of crowding, with more crowded patients having less reduction or an increase in millimetric protrusion on average. Mandibular incisors underwent more extrusion in the non-extraction group with an average extrusion of 2.3mm after treatment, while the extraction group had minimal vertical change and a negligible vertical change of -0.1mm.

There was a statistically significant influence of extractions on the nasolabial angle ($p<0.01$) after adjustment. On average, nasolabial angle increased by 4.5 degrees in the extraction group at the completion of treatment. In the non-extraction group this average change was an increase of 0.5 degrees. Upper and lower lip retraction was also more than 1mm greater for the extraction group. This difference was significantly impacted by both extractions ($p<0.01$) and previous treatment ($p<0.01$).

One-Year Follow-Up (T3)

For evaluation of long-term stability, only patients with treatment success (POSI score of 0 or 1) at the end of treatment (41 had POSI=0, and 19 had POSI =1) were included. This group includes 60 patients, 11 patients in the extraction group and 49 patients in the non-extraction group. 100% of patients from the extraction maintained their successful treatment result. Meanwhile, 89.1% of patients from the non-extraction group maintained their successful result. A Fisher's exact test was done to evaluate this difference but failed to show a statistically significant result ($p=0.58$) due to the limited data available for this timepoint, particularly in the extraction group. Very few patients did not have a stable result, making it more difficult to detect a statistically significant difference. For the eight patients that did not achieve treatment success, three had POSI data at T3. All of these patients maintained their POSI scores from T2 to T3.

DISCUSSION

This study aimed to explore the impact of extractions on AOB correction. The success rates for AOB treatment were similarly high for both extraction and non-extraction treatment groups. However, there were differences between the stability of open bite correction at a one year follow up. Significant relapse was rare for both groups, with 91% of all patients maintaining their successful result. Given that relapse was unexpectedly rare, a larger study would be needed to find a difference in stability. The patients that displayed significant relapse were all part of the non-extraction treatment group, meaning 100% of extraction patients at the final timepoint had a stable result. Janson, *et al.* also saw a stability advantage for extraction patients, estimating that positive overbite is maintained in only 62% of patients treated without extractions and 74% for

patients treated with extractions five years after the completion of treatment. After seeing more stable results for an extraction group, he proposed this difference could be due to differences in dental changes throughout treatment.[6] Similar to this study, he found that patients in the extraction group had less mandibular incisor extrusion. Extrusion is not considered a stable movement, and if open bite correction is largely achieved through this movement the correction may be less stable. For the extraction group incisor retraction and lingual tipping contributed more largely to open bite correction.

The success rates seen in this study were very high, with 93% of patients having a successful outcome. Although we largely expected success, these high rates were somewhat surprising as current literature reports successful AOB correction in 75-80% of patients.[4,6,8] This could be attributed to the method used for evaluating success. Traditionally, cephalometric overbite has been used to assess open bite correction. For this study, we used the Photographic Openbite Severity Index (POSI). Success was defined as a POSI score of 0 or 1, meaning there was positive vertical overlap of at least both central incisors. These scores were chosen as they most closely correlate with cephalometric overbite, which measures overlap of the central incisors. Todoki *et al* also used POSI scores to evaluate open bite correction, but defined treatment success as a POSI score of 0, resulting in a success rate of 80%.[4] Using this definition of success results of this study were similar, with 78% of patients achieving a POSI score of 0. Regardless of evaluation method, statistically significant differences in success were not seen between treatment groups. This finding is in agreement with recent literature, which does not indicate more successful open bite correction for extraction patients.[6,9,10]

The results of this study will be most impactful for patients who are considered borderline and could be treated with or without extractions. For this reason, only patients with some level of crowding were included. One might expect to see lower success rates in this sample, with crowding increasing the difficulty of correcting the open bite. However, the severity of crowding did not impact the ability to achieve positive overbite but did lead to a limited "draw-bridge" effect. For cases with more crowding, extraction spaces were used to resolve crowding and less incisor retraction and uprighting occurred. Because crowding ranged from mild to severe, it was difficult to isolate the impact of extractions. In order to more specifically evaluate this effect, a study with a smaller range of crowding severity would be ideal. However, this sample was not large enough to be evaluated in that manner.

Both treatment groups displayed pre-treatment characteristics commonly seen in patients with this malocclusion, such as increased lower anterior facial height and steep mandibular plane angle.[2,3] Changes in lower anterior facial height and mandibular plane angle were minimal at the completion of treatment for both groups. Mean ANB, SNA and SNB differed by less than one degree between treatment groups at the completion of treatment and were largely comparable to pre-treatment measurements. The lack of clinically significant skeletal change indicates that AOB correction was mainly achieved through dental effects. A more substantial change in skeletal features would likely be seen if patients treated with temporary anchorage devices (TADs) or orthognathic surgery were included.[13]

Soft tissue features are an important part of orthodontic treatment planning, particularly when deciding whether to extract teeth. Previously established changes associated with the removal of teeth include increased lip retraction in reference to the e-plane and an increase in nasolabial

angle.[14,15] As expected, these changes were associated with extraction treatment in this sample. It is important to note that at the initial timepoint patients in the extraction group had upper and lower lips that were more protrusive on average. This difference between treatment groups may have influenced practitioners decision to extract teeth, as these patients may have been more amenable to the profile flattening associated with extractions.

An orthodontist's decision to recommend extractions is multifactorial; considering crowding, protrusion, soft tissue profile and openbite severity. The majority of patients proceded with recommended treatment. High rates of openbite correction indicate that practitioners are successful in using extractions to achieve orthodontic goals, including the desired open bite closure. Long-term stability of openbite correction should also be important consideration when making treatment decisions.

LIMITATIONS

Gathering records from many offices throughout the nation was beneficial in obtaining a sample of this size. We expect increased variation when a great number of diverse practitioners are allowed to employ their preferred fixed appliance treatment. Additionally, the sample was not randomized, which could incorporate bias. For the stability assessment, follow up was only performed at one-year post treatment completion. This is a relatively short follow-up time frame. Not all patients had follow-up data due to the end of the study funding cycle and the protracted nature of treatment.

CONCLUSIONS

Orthodontists achieve high levels of success correcting Anterior Open Bites (AOB) with fixed appliances in adult patients, with similar results for patients treated with or without extractions. The great majority of patients-maintained closure of their openbite at the latest post-treatment follow-up, leaving too few relapse patients to adequately investigate stability. However, a tendency was observed that extraction treatment in AOB patients may be associated with increased stability. Clinically significant changes at the completion of treatment were only seen for dental and soft tissue variables, including more retraction and lingual tipping of incisors in the extraction patients and an associated retraction of soft tissue.

ACKNOWLEDGEMENTS

The original study was funded by NIDCR grant U19-DE-22516. Opinions and assertions contained herein are those of the authors and are not to be construed as necessarily representing the views of the respective organizations or the National Institutes of Health. The informed consent of all human subjects who participated in this investigation was obtained after the nature of the procedures had been explained fully. An internet site devoted to details about the nation's network is located at http://NationalDentalPBRN.org and is conducted under the auspices of the National Dental Practice-Based Research Network (NDPBRN). We gratefully acknowledge all the practitioners and patients who made this study possible. We are also grateful to the network's regional coordinators, Sarah Basile, RDH, MPH, Chris Enstad, BS, and Hannah Van Lith, BA (Midwest); Stephanie Hodge, MA, and Kim Stewart (Western); Pat Ragusa (Northeast); Deborah McEdward, RDH, BS, CCRP, and Danny Johnson (South Atlantic); Claudia Carcele'n, MPH, Shermetria Massingale, MPH, CHES, and Ellen Sowell, BA (South Central); Stephanie Reyes,

BA, Meredith Buchberg, MPH, and Monica Castillo, BA (Southwest). We also thank Kavya Vellala and the Westat Coordinating Center staff, the American Association of Orthodontists (AAO), Jackie Hitner (AAO Librarian), Gregg Gilbert, DDS, MBA (National Network Director), and Dena Fischer, DDS, MSD, MS (NIDCR Program Director).

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Figure 1: Cephalometric Landmarks

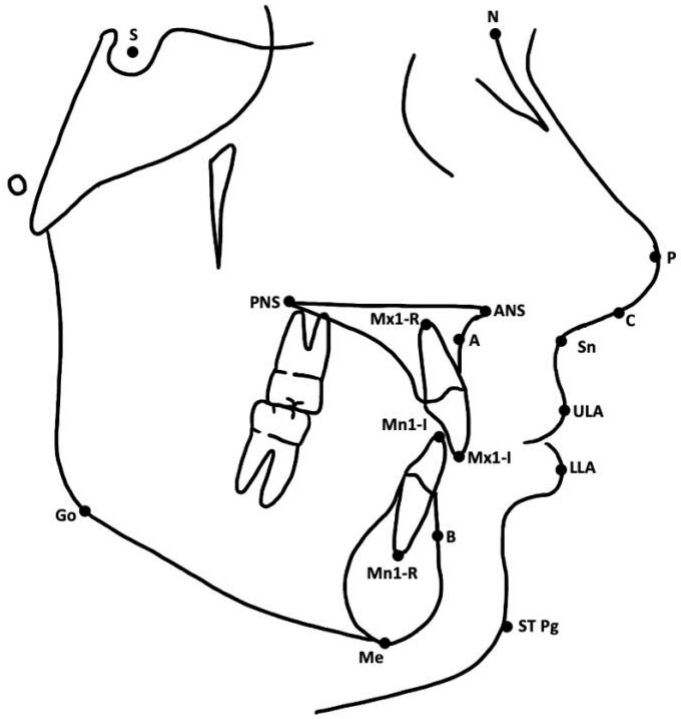

Figure 2: Cephalometric Reference Planes

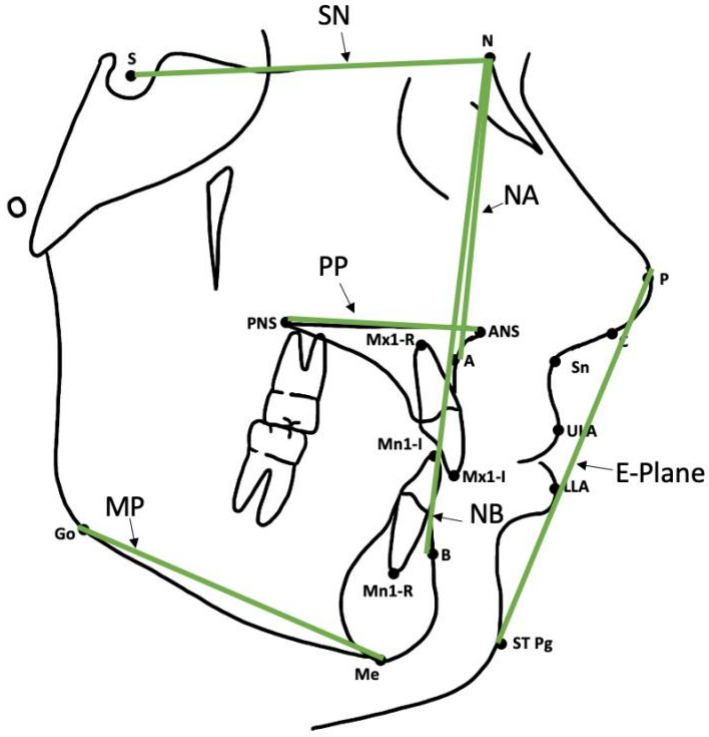

Figure 3: Dentoalveolar Height Cephalometric Measurements

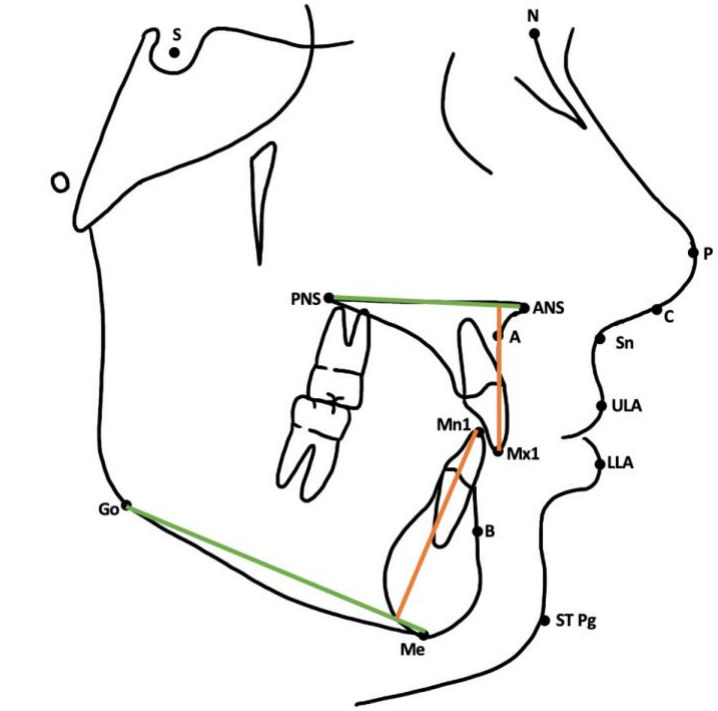

Figure 4: Soft Tissue Cephalometric Measurements

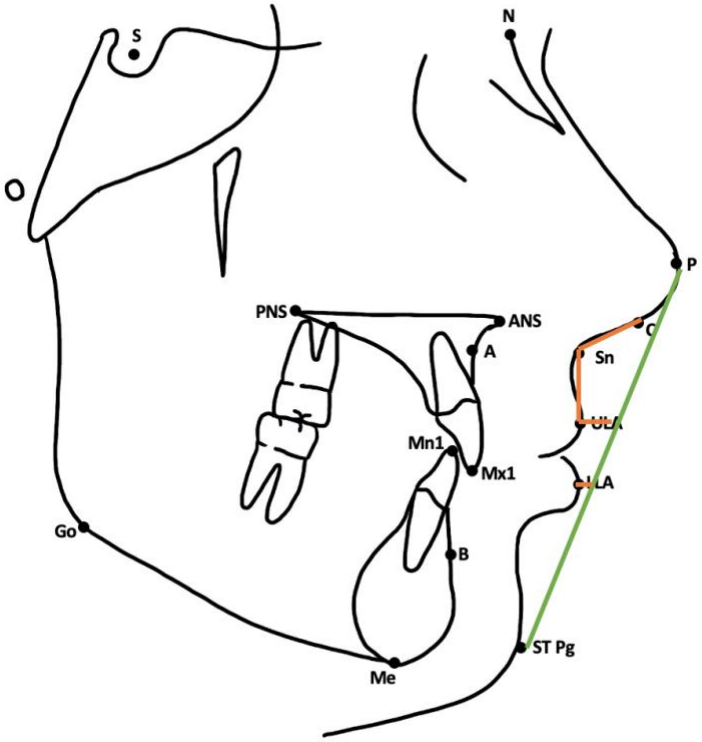

Figure 5: Photographic Openbite Severity Index (POSI)

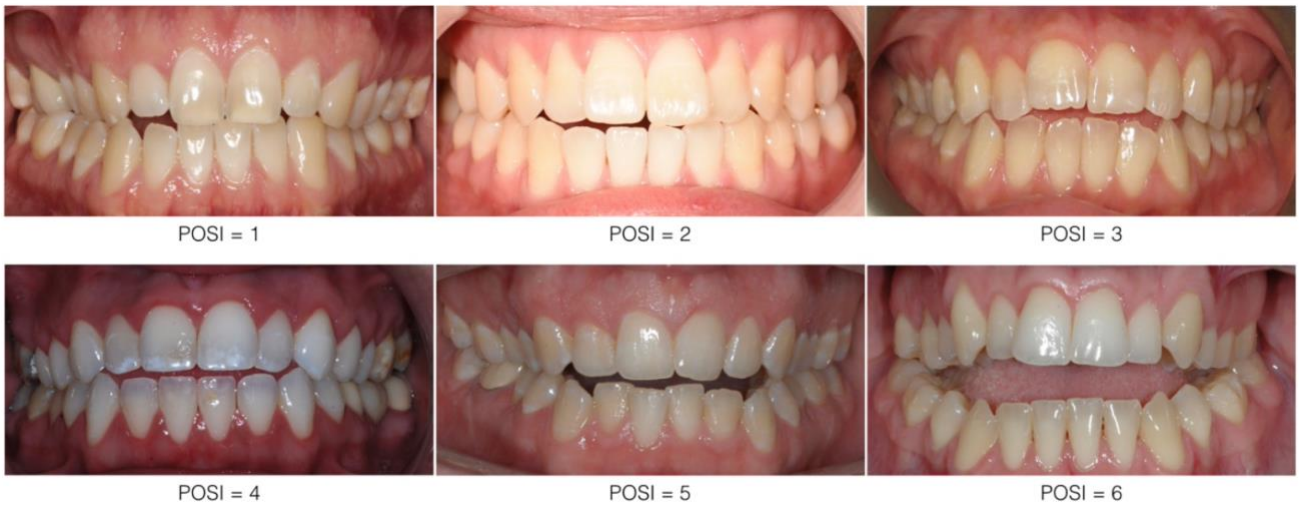

Table 1: Initial Patient Demographics

	All n=115	%	Non-Extraction n=82	%	Extraction n=33	%
Age, Mean (SD)	33.2 (12.0)		34.7 (12.4)		29.6 (10.3)	
Age Group						
18.0 - 20.9	19	16.5	10	12.2	9	27.3
21.0 - 30.9	41	35.7	30	36.6	11	33.3
31.0 - 40.9	33	28.7	23	28	10	30.3
41.0 - 67.1	22	19.1	19	23.2	3	9.1
Gender						
Male	20	17.2	15	18.1	5	15.2
Female	96	82.8	68	81.9	28	84.8
Previous Treatment						
No	79	68.1	52	62.7	27	81.8
Yes	37	31.9	31	37.3	6	18.2
Previous Extraction						
No	107	92.2	74	89.2	33	100
Yes	9	7.8	9	10.8	0	0
Crowding						
Mild (1-3mm)	47	40.5	37	44.6	10	30.3
Moderate (4-6mm)	54	46.6	39	47	15	45.5
Severe (>6mm)	15	12.9	7	8.4	8	24.2

Table 2: Cephalometric Landmark Abbreviations and Definitions

Landmark	Definition
S: Sella Turcica	Center of the sella turcica
N: Nasion	Junction of the nasal and frontal bones at the most posterior point on the curvature of the bridge of the nose
ANS: Anterior Nasal Spine	Most anterior point on the maxilla at the nasal base
PNS: Posterior Nasal Spine	Tip of the posterior nasal spine of the palatine bone
A: A-Point	Point of the deepest concavity anteriorly on the maxillary alveolus
B: B-Point	Point of deepest concavity anteriorly on the mandibular symphysis
Mx1-I	Incisal edge of maxillary incisor
Mn1-I	Incisal edge of mandibular incisor
Mx1-R	Tip of root of maxillary incisor
Mn1-R	Tip of root of mandibular incisor
Me: Menton	The lowest point on the symphysis of the mandible
Go: Gonion	Most inferior point on angle of mandible
P: Pronasale	Most anterior point of the nose
C: Columella	Most anterior point on the columella of the nose
ULA: Upper Lip Anterior	Most anterior point of the upper lip
LLA: Lower Lip Anterior	Most anterior point of the lower lip
ST Pg: Soft Tissue Pogonion	Most anterior point of the soft tissue chin

Table 3: Cephalometric Reference Plane Abbreviations and Definitions

Reference Plane	Definition
SN	Sella-Nasion
NA	Nasion-A Point
NB	Nasion-B Point
PP: Palatal Plane	Anterior Nasal Spine-Posterior Nasal Spine
MP: Mandibular Plane	Gonion-Menton
E-Plane: Esthetic Plane	Pronasale-Soft Tissue Pogonion

Table 4: Cephalometric Measurement Abbreviations and Definitions

Measurement	Definition
Skeletal Measurements	
ANB (°)	A point-Nasion-B point
SNA (°)	SN-A point
SNB (°)	SN-B point
MPSN (°)	MP-SN
LAFH (mm): Lower Anterior Facial Height	ANS-Me
Dental Measurements	
OB (mm): Overbite	Vertical distance between the incisal edge of the maxillary incisors and mandibular incisors
Mx1-PP (°): Maxillary incisor inclination	A measurement of the angle between the palatal plane and a line drawn through the long axis of the maxillary incisor
Mn1-MP (°): Mandibular incisor inclination	A measurement of the angle between the mandibular plane a line drawn through the long axis of the lower incisor
Mx1-I-NA (mm): Maxillary incisor protrusion	Millimetric distance between the incisal edge of the maxillary incisor and NA
Mn1-I-NB (mm): Mandibular incisor protrusion	Millimetric distance between the incisal edge of the mandibular incisor and NB
Mx1-PP (mm): Maxillary incisor vertical position	Millimetric distance of a line drawn from the incisal edge of the maxillary incisor perpendicular to the palatal plane
Mn1-MP (mm): Mandibular incisor vertical position	Millimetric distance of a line drawn from the incisal edge of the mandibular incisor perpendicular to the mandibular plane
Soft Tissue Measurements	
UL-E Plane (mm): Upper lip protrusion	Millimetric measurement of the most anterior point of the upper lip to the esthetic plane
LL-E Plane (mm): Lower lip protrusion	Millimetric measurement of the most anterior point of the lower lip to the esthetic plane
NLA (°): Nasolabial Angle	Angular measurement: Upper Lip Anterior-Subnasale-Columella

Table 5: POSI Scores: T1, T2 and T3

POSI Score	T1		T2		T3	
	Non-Ext n=86 (%)	Ext n=37 (%)	Non-Ext n=82 (%)	Ext n=33 (%)	Non-Ext* n=55 (%)	Ext* n=11(%)
0	0 (0)	0 (0)	65 (79.3)	25 (75.8)	32 (58.2)	9 (81.8)
1	15 (17.4)	8 (21.6)	10 (12.2)	7 (21.2)	17 (30.9)	2 (18.2)
2	17 (19.8)	9 (24.3)	1 (1.2)	0 (0)	1 (1.8)	0 (0)
3	7 (8.1)	2 (5.4)	2 (2.4)	0 (0)	0 (0)	0 (0)
4	29 (33.7)	10 (27)	1 (1.2)	1 (3)	5 (9.1)	0 (0)
5	5 (5.8)	6 (16.2)	2 (2.4)	0 (0)	0 (0)	0 (0)
6	13 (15.1)	2 (5.4)	1 (1.2)	0 (0)	0 (0)	0 (0)

*T3 data includes only those with a successful outcome at T2 (POSI T2= 0 or 1)

Table 6: Cephalometric Measurement Value Means T1 and T2

	T1		T2	
	Non-Ext Mean (sd)	Ext Mean (sd)	Non-Ext Mean (sd)	Ext Mean (sd)
ANB	3.1 (2.3)	3.7 (3.0)	2.9 (2.3)	3.9 (2.8)
SNA	80.1 (3.7)	81.4 (3.6)	80.2 (4.1)	80.5 (3.4)
SNB	77.0 (3.7)	77.7 (3.9)	77.3 (3.9)	76.6 (4.1)
MPSN	38.1(6.2)	38.7 (5.8)	38.1 (6.2)	39.1 (6.2)
LFHmm	69.1(7.1)	68.3 (4.9)	70.3 (6.7)	68.6 (4.0)
OBmm	-2.0 (1.7)	-1.9 (1.6)	1.1 (1.1)	1.3 (1.0)
Mx1PP°	25.1(7.8)	27.3 (7.1)	22.5 (6.6)	16.6 (9.7)
Mn1MP°	29.4(7.3)	33.7 (9.3)	27.3 (6.8)	25.6 (8.8)
Mx1NAmm	5.9(2.6)	7.0 (2.9)	5.6 (2.5)	3.0 (3.3)
Mn1NBmm	6.8(2.7)	8.1 (3.4)	7.3 (2.5)	6.0 (2.8)
Mx1PPmm	28.7(3.7)	29.1 (2.9)	30.7 (3.7)	31.2 (3.0)
Mn1MPmm	40.6(3.9)	41.6 (3.0)	42.9 (4.2)	41.5 (2.6)
UL-E	-4.3(3.2)	-1.6 (3.8)	-4.5 (3.1)	-2.9 (3.5)
LL-E	-1.7(3.2)	0.9 (3.6)	-1.4 (3.2)	-0.5 (3.4)
NLA	107.2 (11.4)	108.4 (9.3)	107.7 (10.7)	113.0 (10.1)

Table 7: Multivariate Regression Analysis: Effect of Extractions After Adjustment

	Estimate	Std. Error	t value	p value
ANB	0.2	0.3	0.8	0.45
SNA	-0.9	0.4	-2.0	0.05
SNB	-1.0	0.3	-3.1	<0.01
MPSN	0.7	0.4	1.9	0.06
LFH	0.2	0.6	0.3	0.76
OB	0.0	0.2	0.1	0.92
U1deg	-6.8	1.5	-4.6	<0.01
L1deg	-6.1	1.2	-5.0	<0.01
U1mm	-3.2	0.5	-6.2	<0.01
L1mm	-2.6	0.4	-7.4	<0.01
U1PP	0.3	0.4	0.8	0.41
L1MP	-1.6	0.5	-3.4	<0.01
ULip	-0.9	0.4	-2.2	0.03
LLip	-1.6	0.4	-4.0	<0.01
NLA	5.1	1.8	2.9	<0.01

Appendix Table 1: Multivariate Linear Regression Analysis

ANB_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	-1.1	0.9	-1.3	0.21
Extract_Fin	0.2	0.3	0.8	0.45
factor(AgeGrp)(20,30]	0.7	0.4	1.6	0.12
factor(AgeGrp)(30,40]	0.8	0.4	1.9	0.06
factor(AgeGrp)(40,99]	0.4	0.5	0.8	0.42
Gend	0.7	0.4	1.7	0.09
PrvTrt	0.0	0.3	-0.1	0.96
PrvExt	-0.2	0.5	-0.3	0.76
factor(Crowding_Score)4	-0.4	0.3	-1.4	0.18
factor(Crowding_Score)5	0.4	0.4	0.9	0.38
ANB	0.8	0.1	12.4	<0.01

SNA_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	9.8	4.2	2.3	0.02
Extract_Fin	-0.9	0.4	-2.0	0.05
factor(AgeGrp)(20,30]	0.3	0.6	0.5	0.61
factor(AgeGrp)(30,40]	0.3	0.6	0.5	0.63
factor(AgeGrp)(40,99]	-0.2	0.7	-0.3	0.78
Gend	0.0	0.5	0.0	0.97
PrvTrt	-0.9	0.4	-2.1	0.04
PrvExt	0.2	0.8	0.3	0.78
factor(Crowding_Score)4	-0.6	0.4	-1.6	0.11
factor(Crowding_Score)5	-0.7	0.6	-1.1	0.28
SNA	0.9	0.1	17.4	<0.01

SNB_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	7.8	3.2	2.5	0.02
Extract_Fin	-1.0	0.3	-3.1	<0.01
factor(AgeGrp)(20,30]	-0.3	0.4	-0.6	0.54
factor(AgeGrp)(30,40]	-0.3	0.5	-0.6	0.53
factor(AgeGrp)(40,99]	-0.2	0.5	-0.4	0.72
Gend	-0.4	0.4	-1.1	0.28
PrvTrt	-0.9	0.3	-2.9	0.01
PrvExt	0.4	0.6	0.7	0.46
factor(Crowding_Score)4	-0.3	0.3	-0.9	0.35
factor(Crowding_Score)5	-0.9	0.5	-2.0	0.04
SNB	0.9	0.0	24.7	<0.01

MPSN_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	-0.2	1.4	-0.2	0.86
Extract_Fin	0.7	0.4	1.9	0.06
factor(AgeGrp)(20,30]	0.3	0.5	0.7	0.50
factor(AgeGrp)(30,40]	0.0	0.5	0.1	0.93
factor(AgeGrp)(40,99]	-0.1	0.6	-0.2	0.82
Gend	0.1	0.4	0.3	0.76
PrvTrt	0.8	0.4	2.0	0.05
PrvExt	-0.6	0.6	-1.0	0.32
factor(Crowding_Score)4	0.3	0.3	0.8	0.43
factor(Crowding_Score)5	1.0	0.5	1.9	0.06
MPSN	1.0	0.0	37.1	<0.01

LFHmm_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	15.0	4.5	3.3	<0.01
Extract_Fin	0.2	0.6	0.3	0.76
factor(AgeGrp)(20,30]	-0.2	0.9	-0.2	0.85
factor(AgeGrp)(30,40]	-0.3	0.9	-0.3	0.75
factor(AgeGrp)(40,99]	0.5	1.0	0.5	0.63
Gend	-0.4	0.9	-0.4	0.66
PrvTrt	0.3	0.7	0.5	0.62
PrvExt	0.2	1.1	0.1	0.88
factor(Crowding_Score)4	0.7	0.6	1.1	0.27
factor(Crowding_Score)5	-0.6	0.9	-0.6	0.53
LFHmm	0.8	0.1	15.9	<0.01

Obmm_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	1.6	0.6	2.6	0.01
Extract_Fin	0.0	0.2	0.1	0.92
factor(AgeGrp)(20,30]	0.6	0.3	1.9	0.06
factor(AgeGrp)(30,40]	0.1	0.3	0.3	0.78
factor(AgeGrp)(40,99]	-0.2	0.3	-0.7	0.52
Gend	-0.1	0.3	-0.3	0.76
PrvTrt	-0.3	0.2	-1.1	0.27
PrvExt	-0.4	0.4	-0.9	0.38
factor(Crowding_Score)4	0.1	0.2	0.6	0.53
factor(Crowding_Score)5	-0.2	0.3	-0.6	0.56
OBmm	0.2	0.1	3.2	<0.01

U1deg_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	26.4	5.7	4.6	<0.01
Extract_Fin	-6.8	1.5	-4.6	<0.01
factor(AgeGrp)(20,30]	-2.4	2.0	-1.2	0.24
factor(AgeGrp)(30,40]	-2.4	2.1	-1.2	0.24
factor(AgeGrp)(40,99]	-5.7	2.4	-2.4	0.02
Gend	-4.9	1.9	-2.6	0.01
PrvTrt	-2.1	1.5	-1.4	0.18
PrvExt	1.6	2.6	0.6	0.53
factor(Crowding_Score)4	1.2	1.4	0.9	0.37
factor(Crowding_Score)5	-2.9	2.1	-1.4	0.17
U1deg	0.3	0.1	3.5	<0.01

L1deg_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	4.2	3.7	1.1	0.26
Extract_Fin	-6.1	1.2	-5.0	<0.01
factor(AgeGrp)(20,30]	-1.0	1.6	-0.6	0.52
factor(AgeGrp)(30,40]	2.1	1.6	1.3	0.20
factor(AgeGrp)(40,99]	0.3	1.8	0.1	0.89
Gend	1.4	1.4	1.0	0.33
PrvTrt	-1.6	1.2	-1.3	0.19
PrvExt	0.1	2.0	0.0	0.97
factor(Crowding_Score)4	2.8	1.1	2.6	0.01
factor(Crowding_Score)5	7.0	1.7	4.2	<0.01
L1deg	0.6	0.1	9.4	<0.01

U1mm_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	7.6	1.7	4.4	<0.01
Extract_Fin	-3.2	0.5	-6.2	<0.01
factor(AgeGrp)(20,30]	-0.7	0.7	-1.1	0.29
factor(AgeGrp)(30,40]	-0.6	0.7	-0.9	0.36
factor(AgeGrp)(40,99]	-1.1	0.8	-1.4	0.17
Gend	-2.2	0.7	-3.4	<0.01
PrvTrt	-0.4	0.5	-0.7	0.51
PrvExt	-0.3	0.9	-0.3	0.77
factor(Crowding_Score)4	0.9	0.5	2.0	0.05
factor(Crowding_Score)5	-0.3	0.7	-0.4	0.68
U1mm	0.4	0.1	4.8	<0.01

L1mm_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	0.7	1.0	0.7	0.48
Extract_Fin	-2.6	0.4	-7.4	<0.01
factor(AgeGrp)(20,30]	0.3	0.5	0.7	0.49
factor(AgeGrp)(30,40]	1.2	0.5	2.5	0.01
factor(AgeGrp)(40,99]	0.9	0.5	1.7	0.09
Gend	0.4	0.4	0.9	0.36
PrvTrt	-0.5	0.4	-1.4	0.17
PrvExt	-0.4	0.6	-0.7	0.49
factor(Crowding_Score)4	0.9	0.3	2.9	0.01
factor(Crowding_Score)5	2.0	0.5	4.1	<0.01
L1mm	0.7	0.1	12.6	<0.01

U1PP_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	6.4	2.2	2.9	0.01
Extract_Fin	0.3	0.4	0.8	0.41
factor(AgeGrp)(20,30]	0.2	0.5	0.4	0.65
factor(AgeGrp)(30,40]	0.1	0.6	0.2	0.82
factor(AgeGrp)(40,99]	0.7	0.6	1.0	0.30
Gend	-0.1	0.5	-0.3	0.80
PrvTrt	-0.3	0.4	-0.7	0.48
PrvExt	-0.1	0.7	-0.1	0.93
factor(Crowding_Score)4	0.4	0.4	1.1	0.29
factor(Crowding_Score)5	0.4	0.6	0.7	0.46
U1PP	0.8	0.1	14.9	<0.01

L1MPmm_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	9.3	3.3	2.9	0.01
Extract_Fin	-1.6	0.5	-3.4	<0.01
factor(AgeGrp)(20,30]	0.2	0.6	0.3	0.75
factor(AgeGrp)(30,40]	0.5	0.7	0.7	0.46
factor(AgeGrp)(40,99]	0.1	0.7	0.1	0.91
Gend	-0.3	0.6	-0.6	0.58
PrvTrt	-0.5	0.5	-1.0	0.33
PrvExt	0.0	0.8	0.0	0.98
factor(Crowding_Score)4	0.6	0.4	1.3	0.18
factor(Crowding_Score)5	0.1	0.7	0.2	0.86
L1MPmm	0.8	0.1	12.9	<0.01

ULip_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	-0.7	1.1	-0.6	0.54
Extract_Fin	-0.9	0.4	-2.2	0.03
factor(AgeGrp)(20,30]	0.0	0.5	0.0	0.98
factor(AgeGrp)(30,40]	-0.2	0.5	-0.4	0.70
factor(AgeGrp)(40,99]	-0.7	0.5	-1.3	0.18
Gend	0.0	0.5	-0.1	0.93
PrvTrt	-0.8	0.4	-2.0	0.05
PrvExt	0.0	0.7	-0.1	0.96
factor(Crowding_Score)4	0.4	0.4	1.2	0.22
factor(Crowding_Score)5	0.5	0.5	0.9	0.37
ULip	0.8	0.0	16.6	<0.01

LLip_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	0.1	1.1	0.1	0.92
Extract_Fin	-1.6	0.4	-4.0	<0.01
factor(AgeGrp)(20,30]	-0.4	0.5	-0.8	0.42
factor(AgeGrp)(30,40]	0.1	0.5	0.1	0.90
factor(AgeGrp)(40,99]	-0.6	0.6	-1.0	0.30
Gend	0.1	0.5	0.2	0.86
PrvTrt	-1.2	0.4	-3.0	<0.01
PrvExt	0.2	0.7	0.3	0.75
factor(Crowding_Score)4	0.7	0.4	1.9	0.06
factor(Crowding_Score)5	1.0	0.6	1.7	0.09
LLip	0.8	0.1	16.1	<0.01

NLA_T2	**Estimate**	**Std. Error**	**t value**	**p value**
(Intercept)	34.1	8.3	4.1	<0.01
Extract_Fin	5.1	1.8	2.9	<0.01
factor(AgeGrp)(20,30]	-3.1	2.2	-1.4	0.17
factor(AgeGrp)(30,40]	-3.6	2.3	-1.5	0.13
factor(AgeGrp)(40,99]	-1.3	2.6	-0.5	0.61
Gend	1.3	2.2	0.6	0.56
PrvTrt	2.7	1.8	1.5	0.14
PrvExt	-0.2	3.1	-0.1	0.95
factor(Crowding_Score)4	0.1	1.6	0.1	0.94
factor(Crowding_Score)5	-1.7	2.6	-0.6	0.52
NLA	0.7	0.1	9.3	<0.01