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The National Dental PBRN Adult Anterior Openbite Study: Treatment Recommendations and Their Association with Patient and Practitioner Characteristics

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Abstract

Introduction: This aim of this paper is to describe and identify the practitioner and patient characteristics that are associated with treatment recommendations for adult anterior openbite patients across the United States.

Methods and Materials: Practitioners and patients were recruited within the framework of the National Dental Practice-based Research Network. Practitioners were asked about their demographic characteristics, as well as their treatment recommendations for these patients. The practitioners also reported on their patients' dentofacial characteristics, and provided initial cephalometric scans and intra-oral photographs. Patients were asked about their demographic characteristics, prior orthodontic treatment, and goals for treatment. Four main treatment groups were evaluated: Aligners, Fixed Appliances, Temporary Anchorage Devices, and Orthognathic Surgery. Extractions were also investigated. Predictive multivariable models were created comparing various categories of treatment, as well as extraction/non-extraction decisions.

Results: Ninety-one practitioners (mostly orthodontists) and 347 patients were recruited from October, 2015 to December, 2016. Increased aligner recommendations were associated with Caucasian and Asian patients, the presence of tongue habits, and female practitioners. TADs were recommended more often in academic settings. Recommendations for orthognathic surgery were associated with demographic factors, like availability of insurance coverage and practitioner race/ethnicity, and dentofacial characteristics, like antero-posterior discrepancies, more severe openbites, and steeper mandibular plane angles. Extraction recommendations were largely associated with severe crowding and incisor proclination.

Conclusions: Both doctor and patient demographic factors, as well as dentofacial characteristics, were significantly associated with treatment recommendations for adult anterior openbite patients.

Introduction:

The prevalence of anterior openbite (AOB) in the United States ranges from 0.6% to 16.5%, varying by age and ethnic group.[1] Despite the relatively low overall prevalence of openbite, it is a condition which prompts many affected individuals to seek treatment, as evidenced by estimates that as many as 17% of patients with skeletal discrepancies present with anterior open bites.[2] The etiology of anterior openbite may be straightforward, such as a digit habit, or multi-factorial, related to skeletal, respiratory, and/or neuromuscular factors.[3,4]

Numerous treatment modalities have been proposed to address anterior openbite malocclusion, including habit devices[5], myofunctional therapy[6], conventional fixed appliances, extraction of teeth[7], clear aligners[8], temporary anchorage devices (TADs)[9], occlusal equilibration[10], and orthognathic surgery[11]. Traditionally, treatments like habit appliances and growth modification have been recommended to children and adolescents, while orthognathic surgery has often been recommended to adults, especially when the openbites are moderate to severe. However, clear aligners and TADs have emerged as alternative techniques to address openbite malocclusions, and case reports indicate that they may be successful even in moderate to severe cases[8,12].

To date, there have been no studies which evaluate treatment recommendations for AOB malocclusions in adults. While a patient's dentofacial characteristics may play the largest role in an orthodontist's treatment recommendations, other factors may also influence treatment recommendations. For example, do treatment recommendations for openbite patients vary depending on the age or experience of the practitioner? Do patient demographics, like age and insurance coverage, play a role? Ultimately, practitioners would like to know which factors play the largest role in treatment recommendations, and whether these factors are based on valid evidence and successful outcomes.

In 2015, the current study was launched within the National Dental Practice-Based Research Network (Network)[13]. The overall study aims are to investigate orthodontic recommendations, patient acceptance of treatment recommendations, treatment success, post-treatment stability, and patient satisfaction related to treatment of adult patients with anterior open bite. A prior publication described the demographic characteristics of the practitioners and patients enrolled in the study[14]. This paper reports on the first aim of the study, specifically, to identify and describe what practitioner and patient characteristics are associated with treatment recommendations in adults with anterior openbite.

Methods and Materials:

Providers recruited for this study were from the six geographic regions (West, Midwest, Southwest, South Central, South Atlantic, and Northeast) of the Network. Institutional Review Board (IRB) approval was obtained from institutions representing the regions: the University of Alabama Institutional Review Board (acting as the Central IRB), the Kaiser Permanente Northwest Institutional Review Board (for the Western region), and the University of Rochester Research Subjects Review Board (for the Northeast region). Practitioners completed an Enrollment Questionnaire (EQ) when joining the network, which collected information on the practitioners and their practices. Additional questionnaires completed by practitioners and patients at enrollment provided patient demographic information, dentofacial characteristics of the patients, and details related to treatment. For each patient, practitioners were requested to list their most recommended plan, and if the patient did not accept that plan, recommend up to two additional plans, if offered to the patient. All study forms can be accessed at http://nationaldentalpbrn.org/anterior-openbite-malocclusions-in-adults-recommendations-treatment-and-stability.php

The inclusion criteria for practitioners were as follows:

- Is an orthodontist or a dentist that routinely performs orthodontic treatment.
- Estimates he/she can recruit 3–8 adult patients in active treatment for AOB, and expects to have treatment completed within 24 months of enrollment into the study.
- Routinely takes cephalometric radiographs (cephalograms) before and after treatment.
- Has the ability to upload (via internet) de-identified cephalometric radiographs and digital intra-oral frontal photographs to a central repository.
- Affirms that the practice can devote sufficient time in patient scheduling to allow focused recording of all data required for the study.
- Does not anticipate retiring, selling the practice, or moving during the study.

For patients, the inclusion criteria were:

- Must be at least 18 years of age at time of enrollment.
- Must have 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 of them can contact teeth in the opposing arch. (This was determined by examining the patient's initial cephalogram, intra-oral photographs, and/or initial plaster or digital casts.)
- Must be in active treatment for AOB, and expect to have treatment completed within 24 months of enrollment into the study.
- Must have an initial cephalogram (taken prior to the beginning of treatment). A cephalogram created from a cone-beam CT scan is acceptable.

Recruitment was restricted to adults in order to eliminate the influence of growth on treatment outcome. Additionally, to avoid selection bias, practitioners were requested to enroll all eligible patients. Practitioner and patient questionnaires were sent to regional centers where they were reviewed for completeness and entered into a centralized database, with range and logic checks. The statistician provided the study principal investigator with data outliers to review for clinical "reasonableness/validity." Questionable values were sent to regional coordinators to review for accuracy of data entry, and subsequent review of clinical records was conducted as needed.

Alongside the questionnaires, pre-treatment cephalometric radiographs and frontal intra-oral digital photographs were collected and sent electronically to a central site. The radiographs were imported into Dolphin imaging software (Patterson Dental, St. Paul, MN), and custom cephalometric analyses were performed. This has been previously described.[13]

Data Analysis

The following were evaluated:

- Practitioner characteristics included specialization (orthodontist or general dentist), country of dental school, gender, age, race and Hispanic/Latino

ethnicity, years in dental practice, geographic region of practice, and practice type.

- Patient characteristics included demographics (gender, age, race and Hispanic/Latino ethnicity, insurance coverage, and level of education) and prior orthodontic experience. Dentofacial characteristics included profile, molar classification, arch length discrepancy, the presence or absence of posterior crossbite, and habits on recommended treatment. Additionally, the following cephalometric characteristics were evaluated: ANB angle, mandibular plane angle (MPA), posterior facial height (PFH), upper and lower incisor angulation, overbite (OB), and overjet (OJ).
- An index was developed to score the relative severity of the patients' openbite using the intraoral frontal photographs. The photographic openbite severity index (POSI) has six categories, based on the type and number of teeth that do not have vertical overlap (Figure 1). The categories are:

  1. 1 or 2 maxillary (MX) lateral incisors without vertical overlap (but both MX central incisors have vertical overlap)
  2. 1 MX central incisor without vertical overlap (the other MX central has vertical overlap)
  3. 2 MX central incisors without vertical overlap (at least one MX lateral has vertical overlap)
  4. All four MX incisors without vertical overlap
  5. All anterior teeth without overlap (canine to canine)
  6. Category 5, plus at least one premolar without vertical overlap

Cephalometric images from ten patients were randomly selected to measure inter- and intra-rater reliability by two investigators. Each identified landmarks from which 24 measurements were automatically calculated, and then 4 weeks later, repeated the procedures. Both inter- and intra-rater reliability were excellent as determined using intraclass correlations. The mean inter-rater reliability was 97% (range: 91% to 99%) and the mean intra-rater reliability was 98% (range: 95% to 99%). For the POSI, 20 frontal intra-oral images were rated twice, one month apart. The inter-rater mean % agreement was 92.5% and the mean kappa was 95.5%. The intra-rater mean % agreement was 97% and the mean kappa was 98.5%.

Treatment recommendations were divided into four mutually exclusive categories:

1. ALN: Aligners (patients recommended fixed appliances, temporary anchorage devices (TADs) or orthognathic surgery were excluded)
2. FA: Fixed appliances (patients could also have been recommended aligners, but patients recommended TADs or orthognathic surgery were excluded)

3. TADs: temporary anchorage devices (patients could also have been recommended aligners and/or fixed appliances, but patients recommended orthognathic surgery were excluded)

4. SX: Orthognathic surgery (patients could also have been recommended aligners, fixed appliances, and/or TADs)

In general, these treatment modalities indicate an increasing ability to manage more complex malocclusions, as well as an increasing level of invasiveness. When patients were recommended combinations of appliances, for example aligners and fixed appliances, or fixed appliances with TADs, they were placed into the most invasive treatment category. Because extractions are sometimes employed as a strategy for openbite closure, factors associated with recommendations for extractions were also investigated.

Frequencies of treatment recommendations were first obtained according to the four treatment categories of primary interest. Patients were also categorized based on prior orthodontic treatment, missing teeth, and recommendations for tooth extraction. Then the frequencies of practitioner characteristics, patient demographic and dentofacial characteristics, and the POSI were obtained according to the four recommended treatment categories. Descriptive statistics (e.g., means, standard deviations) of cephalometric measures and patient age were performed.

Due to clustering of patients within practitioners, all statistical significance was assessed by entering each practitioner/patient characteristic into a logistic regression model that used a generalized estimating equations (GEE) method that adjusted for clustering of patients within the practice. This was implemented using PROC GENMOD in SAS with the CORR=EXCH option.

Predictive models were developed to investigate the four categories of treatment recommendations. Specifically, the differences between recommendations for adjacent treatment categories (ALN vs FA, FA vs TADs, and TADs vs SX) and for orthognathic surgery vs the other three categories combined (ALN, FA, and TADs) were assessed. The multivariable predictive models were built by entering all characteristics with $p<0.10$, and using backwards elimination until all characteristics had $p<0.10$, except in the orthognathic surgery vs other three treatment groups, which utilized a $p<0.05$ value. This was done due to the small number of patients in the aligner and TAD treatment categories. Extractions and prior orthodontic treatment were included in the initial model building for the treatment recommendations, but were removed if they did not attain and retain significance. Supplemental Tables 1–4 display practitioner, patient demographic, dento-facial, and cephalometric associations for each of the treatment comparisons.

Separate predictive models were also developed for extraction recommendations, as extractions are sometimes performed to allow a drawbridge effect (the overbite deepens as the incisors are uprighted during retraction)[15]. In these models, patients were excluded from analyses if they were already missing four premolars, as they would not likely be candidates for additional extractions. Additionally, extraction patients were defined as patients who were referred for extraction of anterior teeth or premolars, as those would be the most

common strategies to address crowding and/or openbite closure. Patients who had only 3rd molar removal recommendations were not classified as extraction patients. (We did perform sensitivity analyses in which patients who had only third molars recommended for extraction were classified as extraction patients. Because the results did not differ from our initial model, we only present results using our extraction model as described above.) All analyses were performed using SAS software (SAS v9.4, SAS Institute Inc., Cary NC).

Results:

A total of 91 practitioners were recruited from October 2015 through June 2016, almost all being orthodontists. These practitioners exhibited a large age span, with a mean age of 49 years (SD=10). Eighty-six percent attended dental school in the U.S. and the mean number of years since graduating was 22 (SD=10). The practitioners were primarily Caucasian (62%) and Asian (24%). Twenty-six percent were female, and 75% were in private practice. Twelve percent practiced in academic settings.

From October 2015 to December 2016, 358 patients were enrolled. Eleven did not meet the inclusion criterion for a pre-treatment openbite, leaving 347 patients. The mean pre-treatment overbite measured on lateral cephalograms was −2.4 mm. Over 66% of the patients fell into POSI categories 4, 5, or 6, indicating that they had no vertical overlap of all four incisors. In some analyses, we collapsed the POSI categories into 1–3 vs 4–6. The mean age of the enrolled patients was 31.4 years old and 74% were female. Additional information about enrolled practitioners and patients has been previously reported[13].

For 150 patients, practitioners reported only offering one treatment recommendation, while for 130 patients, two options were provided. Sixty-seven patients were provided with three treatment options. For the analyses, the first recommendation for the patient was used, as it represented what the practitioner felt would be the most ideal treatment for the patient. 345 patients were recommended one of the four main treatments: 35 (10%) were recommended aligners (ALN), 146 (42%) were recommended fixed appliances (FA), 35 (10%) were recommended temporary anchorage devices (TADs), and 129 (37%) were recommended orthognathic surgery (SX). A total of 134 patients (39%) reported prior orthodontic treatment. (Table 1)

At least one tooth was missing in 201 patients (58%), a majority of whom were missing only third molars (63%, N=127). Of the 74 patients who were missing other teeth, 7 were missing incisors, 5 canines, 39 premolars, and 37 1st or 2nd molars. Only 14 patients were missing four premolars, leaving 331 patients in our analyses investigating extraction recommendations.

Practitioner characteristics (Table 2)

Due to the very low number of patients (about 1%) from general dentists, no analyses were performed separately for their recommendations. It was interesting to note that one general dentist recommended TADs to multiple patients.

In descriptive analyses, female practitioners were three times more likely to recommend aligner therapy to correct anterior open bite than males (20% vs 7%). Caucasian and Asian orthodontists were more likely to recommend surgical treatment compared to orthodontists of other race/ethnicities (41% vs 11%). Older practitioners tended to recommend more aligners and less TADs. Practitioners in academic settings recommended more TADs. Aligners were recommended to 12% - 18% of patients in the West, Southwest, and Northeast regions, while aligner treatment was not recommended as the ideal treatment to any patients in the other three regions.

Patient demographics (Table 3)

The majority of the patients were female (74%), Caucasian (55%), and had some form of dental or medical insurance (78%). In descriptive analyses, male patients received slightly higher percentages of TAD and surgery recommendations. Caucasian patients received more surgical recommendations than patients of other races/ethnicities. Insurance coverage for orthognathic surgery was a major factor, with 68% of patients receiving a surgical recommendation if they had insurance that covered orthognathic surgery, and 26% receiving a surgical recommendation if they did not have coverage. A trend was observed that clear aligner therapy was recommended more often to patients with higher levels of education. Aligner therapy and TADs were about two times more likely to be recommended to patients who had undergone prior orthodontic treatment.

Patient dentofacial characteristics (Table 4)

A majority of patients had a convex profile (54%), no posterior crossbite (58%), a high angle facial pattern (59%) and POSI score 4–6 (68%). About one-third had mild (35%) or moderate crowding (31%) in either the maxillary or mandibular arch. Class I malocclusions were present in 41% of the patients, while 31% were Class II and 28% were Class III.

In descriptive analyses, the severity of molar relationship had a positive influence on the recommendations for surgery. Surgery was recommended to 58% of patients with greater than half-cusp Class II molar relationship and 40% of patients with more than half-cusp Class III molar relationship, compared to 21% of the patients who were Class I or within a half-cusp of Class I. The presence of posterior crossbite was also a factor in surgical recommendations. Surgery was recommended to 24% of patients with no posterior crossbite, 47% of patients with unilateral posterior crossbite, and 63% of patients with bilateral posterior crossbite. High angle facial patterns also were associated with the higher percentages of surgical recommendations, compared to normal or short facial patterns. There were no clear relationships between tongue or thumb habits and recommendations for treatment, but aligners seemed to be recommended more often to patients with tongue thrusting or posture habits. Surgery was recommended to 22% of the patients who fell in POSI categories 1–3, while it was recommended to 44% of patients who fell into categories 4–6.

Patient cephalometric (ceph) measures (Table 5)

Consistent with the vertical pattern of the face, patients with larger mandibular plane angles had higher recommendations for surgery; the mean mandibular plane angle was 41.5 degrees

for surgical patients and 37.2 degrees for non-surgical patients. Also, larger openbites were associated with higher rates of surgical recommendations. Patients with recommendations for fixed appliances tended to have the most proclined incisors.

Extractions (Table 6)

Ninety patients were recommended to have at least one tooth extracted. Of these, 23 were recommended only third molar removal. In the remaining 67 patients, 61 were recommended premolar extractions, and 6 were recommended removal of anterior teeth. Thirty-four of the premolar extraction recommendations were for four premolars. Extractions were much less frequent in patients recommended for aligner therapy (only 2 of 35 (6%) aligner patients had recommendations for non-molar extractions, compared to 9 – 30% in the other treatment categories). Patients who reported prior orthodontic treatment were also less likely to be recommended extractions.

No specific practitioner characteristics were associated with extraction recommendations (Supplemental Table 1). With respect to patient demographics, extractions were more commonly recommended to younger patients and to those who had prior treatment (Supplemental Table 2). Several patient dentofacial characteristics were associated with increased extraction recommendations, especially increased crowding (Supplemental Table 3), convex profiles, and the absence of tongue thrust habits and bruxing. Cephalometrically, increased ANB angles, mandibular planes angles, and increased mandibular incisor proclination were related to more extraction recommendations (Supplemental Table 4).

PREDICTIVE MODELS (Table 7):

In order to account for potentially confounding variables, we developed multivariable predictive models for the main treatment recommendations, as well as extractions.

Aligners vs Fixed Appliances: The predictive model for patients recommended aligners vs fixed appliances had only two significant factors. Caucasian and Asian patients were recommended aligners almost 3 times as often as African American or Hispanic/Latino patients. Additionally, patients with tongue posture habits were 2.4 times more likely to be recommended aligners over fixed appliances. While female practitioners recommended aligners more than three times as often as male practitioners in the final model, the p-value was slightly greater than 0.05.

Fixed Appliances vs TADs with fixed appliances: The prediction model for fixed appliances vs TADs included four variables with $P<0.10$. Practitioners from private practice settings were much less likely to recommend TADs than practitioners in academic settings (OR=0.2, P=0.03). For each additional degree of upper and lower incisor proclination, FA alone were about 5 – 10% more likely to be recommended than FA with TADS. Also, African American and Hispanic/Latino patients were more than 3 times less likely to receive recommendations for TADs, compared to Caucasian or Asian patients.

TADs vs Orthognathic Surgery: The strongest predictor for a surgical recommendation over TADs was the availability of insurance coverage for orthognathic surgery. A second

predictor for surgical recommendations was having a Class II or Class III malocclusion, in conjunction with an anterior openbite. Finally, each mm of additional openbite severity was associated with 1.4 times greater odds of receiving a surgical recommendation than one for TADs.

Orthognathic Surgery vs Aligners, Fixed, and TADs combined: When a prediction model was developed for orthognathic surgery vs any other kind of less invasive treatment, several factors were identified. In decreasing impact, they were the race/ethnicity of the practitioner (OR=5.8), the availability of insurance coverage for SX (OR=3.8), the presence of posterior cross-bite (OR=3.6), A-P molar discrepancies (OR=3.4), less severe overbite (OR = 0.87 for every mm), and increased mandibular plane angle (OR = 1.09 for every degree).

Extractions: A predictive model was developed for extractions, excluding patients missing four premolars. We found that increased age and presence of tongue habits were associated with less extraction recommendations, while severe crowding and increased mandibular incisor proclination were associated with more extraction recommendations. Of these, severe crowding had by far the greatest impact, with an odds ratio of 8.

Discussion:

This paper provides a snapshot of treatment recommendations made by U.S. practitioners (almost all being orthodontic specialists) for their adult openbite patients from October 2015 to December 2016. Eighty-five percent of the 88 orthodontists were in private practice settings. They largely reflected the American Association of Orthodontists (AAO) membership in terms of gender, age, race, Hispanic/Latino ethnicity, practice location, and experience[16]. The exception was a higher percentage of academicians in our sample compared to the AAO membership as a whole.

The categorization of treatment into four major groups was done to investigate the rationale behind treatment recommendations. Obviously, health care providers should attempt to recommend the most appropriate treatments, based on each patient's condition. While some patient characteristics were significantly associated with treatment recommendations, there were other factors unrelated to the patient's malocclusion that also were significantly associated with treatment recommendations.

The predictive models for the four main types of treatment are the most important findings from our analyses. These models allowed us to compare recommendations while accounting for potentially confounding factors. Specifically, the orthognathic surgery/no-surgery decision may be of most interest, due to the invasiveness and risks of surgery. While more severe dentofacial characteristics were associated with surgical recommendations, there were several other factors related to higher surgical recommendations. These included practitioners who were Caucasian or Asian, and the availability of insurance coverage for orthognathic surgery. In fact, the race/ethnicity of the practitioner was associated with the highest odds of receiving a surgical recommendation (OR = 5.8), and the impact of insurance coverage on a surgical recommendation (OR = 3.8) was similar to the highest

dentofacial characteristics (posterior cross-bite, OR = 3.6, and Class II or Class III malocclusion, OR = 3.4). This model indicates that a practitioner's own preference for surgery, as well as his or her perception of a patient's acceptance and ability to afford the procedure, may play a major role in surgical recommendations. While these recommendation biases may exist, it may be more important to know how dentofacial characteristics impact treatment success, which we plan to investigate.

Our ability to create a predictive model for aligners vs fixed appliances was hampered by the small number of patients who received recommendations for aligners. Only two factors, Caucasian or Asian race/ethnicity compared to other races/ethnicities, and the presence of a tongue habit, exhibited statistically significant relationships with aligner recommendations. Although the percentage of extraction patients was lower in patients with aligner recommendations (only 2 of the 35 aligner patients were recommended non-third molar extractions) this relationship was not significant in the final model. The higher rate of recommendations for aligners in patients with tongue habits is interesting, as no studies could be found reporting the use of aligners to address tongue habits. Perhaps this relationship is due to the reluctance to extract teeth in patients with tongue habits, but we did control for extraction in our model building. The absence of aligner recommendations to any patients in three out of our six regions was surprising, and may have been related to preferences of the practitioners and/or patients in those regions.

When comparing fixed appliances to TADs in a multivariable predictive model, four variables exhibited statistical significance. Clearly, in our sample, receiving treatment in an academic setting predisposed patients to TAD recommendations. This may be explained by the teaching mission of academic centers, and the need for faculty and students to become familiar with these techniques. Interestingly, the degree of openbite or the steepness of the mandibular plane were not associated with TAD recommendations, which might indicate that practitioners do not yet agree on the indications where TADs may be a useful adjunct to fixed appliances. Similar to the situation with aligners, Caucasians and Asian patients received more TAD recommendations. The decreased recommendations for TADs when incisors were more proclined was not expected, as TADs could provide additional anchorage for retraction.

When comparing TADs to orthognathic surgery, the lack of insurance coverage for surgical treatment was significantly associated with an increased likelihood of a TAD recommendation by almost three times. Class I malocclusions and less severe openbites were also associated with more TAD recommendations. A recent systematic review indicated that posterior intrusion with TADs is possible, resulting in mandibular autorotation[17]. This effect is similar to maxillary impaction surgery, without the invasiveness of orthognathic surgery[11]. Therefore, it was hypothesized that the characteristics for patients receiving recommendations for TADs and surgery would be similar. In fact, the variable most strongly associated for TAD recommendations was the absence of insurance coverage for orthognathic surgery, which may indicate that the use of TADs is a viable alternative when surgery is not available. With respect to molar classification, TADs seem to be recommended more when there was no concomitant A-P skeletal discrepancy. Also, for each

additional mm of openbite severity, the odds of a surgical recommendation vs a TAD recommendation increased by 40%.

There were several other interesting findings regarding clear aligners and TADs. In a prior paper looking at practitioners' general strategies for open bite treatment, 33% indicated that they used aligners frequently and 48% occasionally[14]. However, in this sample of 347 patients, only about 10% of the patients were recommended aligners as a first option. Similarly, 12% of practitioners self-reported frequent use of TADs for openbite and 62% occasionally, but in this sample, TADs were only recommended to 10% of the patients as part of the most ideal plan. Thus, while practitioners may self-report relatively high adoption of these two techniques, they may not yet recommend them as the most ideal option. Additionally, while we might predict higher use of aligners in mild openbites and higher use of TADs in severe openbites, these patterns were not observed. This may indicate that practitioners are still exploring the best indications for these techniques in adult openbite patients. Since aligners and TADs are less invasive than orthognathic surgery, they are appealing to practitioners and patients, especially if openbites can be predictably closed and exhibit good stability.

With respect to extractions, they were largely not performed unless crowding was moderate to severe. While the potential for a drawbridge effect can assist in openbite closure, practitioners may be less inclined to perform extractions unless there is significant crowding or protrusion due to the tendency for openbite patients to have forward tongue posture. A recent systematic review indicates that extraction patients tended to be have more severe pre-treatment openbites, and about 1 mm more of absolute openbite closure at the end of treatment, providing some support for this effect.[18]

Limitations:

One limitation of this study is that the sample of practitioners was not random or consecutively chosen. Practitioners volunteered to participate, and it is possible these practitioners may have a special interest in openbite malocclusions, and likely, specific treatment preferences. However, as previously mentioned, the demographic composition of our practitioners was very similar to that of the AAO members, with the exception that our study included more practitioners from academic settings. Likewise, patients were not randomly chosen, but we did ask the practitioners to consecutively enroll every patient who met the inclusion criteria.

A clustering effect is well established in studies that first recruit practitioners and then patients[19]. Practitioners were able to enroll up to 15 patients, and there could be treatment and/or proficiency biases. For example, one practitioner submitted 14 cases, 11 of whom were treated with clear aligners. One clinician submitted three cases, all of whom were treated with TADs. Adjustment for clustering was performed in the analyses, but residual effects could remain.

Another significant limitation was the small number of patients who received TAD and clear aligners recommendations (only 35 in each group), as well as the number of independent variables that were assessed for all treatment options. Even with combining some

independent variable categories (e.g., practitioner/practice characteristics, patient demographics, and dentofacial characteristics), there were some predictor/outcome combinations with no patients, thereby precluding modeling of those relationships. This is well illustrated in the case of aligner recommendations, as in three of the six regions, clear aligners were not recommended to any patients. Clearly a difference in recommendation patterns exists, but not one that could be modelled. Again, some caution must be employed in interpreting the analyses involving the aligner and TAD groups, due to the small number of practitioners and patients.

Conclusions:

The primary treatment recommendations for four major categories of orthodontic treatment were investigated. Increased aligner recommendations were associated with Caucasian and Asian patients, the presence of tongue habits, and female practitioners. TADs were recommended more often when patients were seen in academic settings. Surgical recommendations were associated with both demographic factors (availability of insurance, Caucasian and Asian practitioners) and dentofacial characteristics (transverse or A-P discrepancies, larger openbites, and steeper mandibular plane angles). Recommendations for extractions were largely associated with severe crowding, and to a lesser degree, proclined incisors.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Highlights

1. 91 practitioners and 347 adult patients with anterior openbite were recruited for this study to investigate treatment recommendations.
2. The main categories of treatment were aligners, fixed appliances, temporary anchorage devices (with fixed appliances), and orthognathic surgery (with fixed appliances.) Extraction recommendations were also investigated.
3. Aligner recommendations were associated with practitioner and patient demographic factors, TADS were recommended more often in academic settings, and orthognathic surgery was associated with practitioner ethnicity, insurance coverage, and more severe dentofacial characteristics.
4. Extractions were largely recommended for patients with severe crowding, and to a lesser degree, proclined incisors.

1. Treatment recommendations were investigated in adult patients with anterior openbite
2. Participants included 91 practitioners and 347 patients
3. Aligner recommendations were associated with practitioner and patient demographic factors
4. TADS were recommended more often in academic settings
5. Orthognathic surgery was associated with practitioner ethnicity, insurance coverage, and more severe dentofacial characteristics.
6. Extractions were recommended for patients with severe crowding, and sometimes, proclined incisors.

Figure 1.

The photographic openbite severity index (POSI) has six categories, based on the type and number of teeth that do not have vertical overlap. It was developed to score the relative severity of the patients' openbite using the intraoral frontal photographs.

Table 1.

Distribution of 345 patients according to ideal treatment category, prior orthodontic treatment, or missing teeth

	Overall		Prior orthodontic treatment		Missing teeth: Any		Missing teeth: Any tooth other than 3rd molar	
	N	**%**	**N**	**Row %**	**N**	**Row %**	**N**	**Row %**
ALL:			134		201		74	
Treatment category[1]								
Aligners	35	10%	18	51%	23	66%	6	17%
Fixed appliances (includes 4 aligners)	146	42%	45	31%	72	49%	34	23%
Temporary Anchorage Devices (includes 6 aligners without fixed; 33 were mini-screws and 2 were mini-plates)	35	10%	20	57%	23	66%	9	26%
Orthognathic surgery (includes 7 aligners, no fixed, 2 aligners and fixed, 118 only fixed, and 2 fixed and TADs (mini-screws)	129	37%	51	40%	83	64%	25	19%
cluster adjusted p-values			*p=0.02*		*p=0.03*		*p=0.7*	
Prior orthodontic treatment								
No	210	61%			112	53%	45	21%
Yes	134	39%			88	66%	29	22%
cluster adjusted p-values					*p=0.12*		*p=0.99*	

[1] Two patients were not recommended any of the 4 primary treatments of interest, and were thus excluded from analysis

P-values adjusted for patient clustering within practitioner using generalized estimating equations

Table 2.

Practitioner/practice characteristics according to most ideal treatment recommendation category

			Treatment category[1]								Cluster adjusted[4] p-values			
	ALL (N=345)		Aligners only (N=35)		Fixed appliances (N=146)		Temporary Anchorage Devices (N=35)		Orthognathic surgery (N=129)		ALN vs. FA	FA vs. TADs	TADs vs SX	SX: yes/no
Practitioner characteristics	**N**	**Col %[2]**	**N**	**Row[3] %**	**N**	**Row[3] %**	**N**	**Row[3] %**	**N**	**Row[3] %**	**p**	**p**	**p**	**p**
Specialty											NE[5]	NE	NE	NE
General practice	3	1%	0	0%	0	0%	3	100%	0	0%				
Orthodontist	342	99%	35	10%	146	43%	32	9%	129	38%				
Country trained in											0.99	.9	0.4	0.98
United States	279	81%	28	10%	124	44%	24	9%	103	37%				
Other	66	19%	7	11%	22	33%	11	17%	26	39%				
Gender											0.06	0.16	0.4	0.7
Male	254	74%	17	7%	112	44%	27	11%	98	39%				
Female	91	26%	18	20%	34	37%	8	9%	31	34%				
Race/ethnicity											NE	NE	NE	0.007
Caucasian	200	58%	13	7%	73	37%	20	10%	94	47%				
Asian	101	29%	13	13%	44	44%	14	14%	30	30%				
Hispanic/Latino	38	11%	9	24%	24	63%	1	3%	4	11%				
Other/unknown	6	2%	0	0%	5	83%	0	0%	1	17%				
Age											0.8	0.8	0.12	0.06
< 45 yeaars	134	39%	13	10%	70	52%	14	10%	37	28%				
45 – 54 years	78	23%	10	13%	20	26%	13	17%	35	45%				
55 – 64 years	110	32%	3	3%	51	46%	7	6%	49	45%				
65+ years	23	7%	9	39%	5	22%	1	4%	8	35%				

			Treatment category[1]								Cluster adjusted[4] p-values			
	ALL (N=345)		Aligners only (N=35)		Fixed appliances (N=146)		Temporary Anchorage Devices (N=35)		Orthognathic surgery (N=129)		ALN vs. FA	FA vs. TADs	TADs vs SX	SX: yes/no
Practitioner characteristics	**N**	**Col %[2]**	**N**	**Row[3] %**	**N**	**Row[3] %**	**N**	**Row[3] %**	**N**	**Row[3] %**	**p**	**p**	**p**	**p**
Years since dental degree											0.9	0.7	0.08	0.13
< 10 years	37	11%	3	8%	23	62%	4	11%	7	19%				
10 – 19 years	129	37%	12	9%	56	43%	15	12%	46	36%				
20 – 29 years	85	25%	8	9%	26	31%	12	14%	39	46%				
30+ years	93	27%	12	13%	41	44%	4	4%	36	39%				
Type of practice											0.4	NE	NE	0.4
Solo, private prtice	154	45%	15	10%	56	36%	17	11%	66	43%				
Owner, non-solo private	72	21%	8	11%	37	51%	3	4%	24	33%				
Associate in private	35	10%	7	20%	21	60%	3	9%	4	11%				
Preferred provider	15	4%	1	7%	8	53%	0	0%	6	40%				
Academic	64	19%	4	6%	22	34%	12	19%	26	41%				
Region											NE	NE	NE	0.6
Western	161	47%	20	12%	55	34%	19	12%	67	42%				
Midwest	33	10%	0	0%	17	52%	2	6%	14	42%				
Southwest	38	11%	7	18%	10	26%	6	16%	15	39%				
South Central	20	6%	0	0%	10	50%	0	0%	10	50%				
South Atlantic	38	11%	0	0%	23	61%	5	13%	10	26%				
Northeast	55	16%	8	15%	31	56%	3	5%	13	24%				

[1] Treatment categories are mutually exclusive (see Table 1); 2 are excluded as none of the 4 primary treatments above were recommended

[2] Overall column percent (denominator=345); columns not summing to 100 are due to rounding

[3] Row %: Percent of specified treatment within category of practitioner/practice characteristic

[4] Adjusted for patient clustering within practitioner using generalized estimating equations

[5] NE: Not estimable

Table 3.

Patient demographics and prior orthodontic treatment according to most ideal treatment recommendation category

			Treatment category[1]								Cluster adjusted[4] p-values			
	ALL (N=345)		Aligners only (N=35)		Fixed appliances (N=146)		Temporary Anchorage Devices (N=35)		Orthognathic surgery (N=129)		ALN vs. FA	FA vs. TADs	TADs vs SX	SX: yes/no
Patient demographics	**N**	**Col %[2]**	**N**	**Row[3] %**	**N**	**Row[3] %**	**N**	**Row[3] %**	**N**	**Row[3] %**	**p**	**p**	**p**	**p**
Gender											0.6	0.06	0.6	0.4
Male	91	26%	10	11%	32	35%	12	13%	37	41%				
Female	253	74%	25	10%	113	45%	23	9%	92	36%				
Age (years)											0.6	NE[5]	0.2	0.4
18–20 years	57	17%	4	7%	21	37%	5	9%	27	47%				
21–30 years	155	45%	15	10%	67	43%	15	10%	58	37%				
31–40 years	76	22%	10	13%	35	46%	10	13%	21	28%				
41 and older	56	16%	6	11%	22	39%	5	9%	23	41%				
mean age (sd)	31.4	(11.2)	33.7	(12.6)	30.9	(10.3)	32	(10.7)	30.9	(12.1)				
Race/ethnicity											NE	NE	0.7	0.04
Caucasian	188	55%	19	10%	54	29%	23	12%	92	49%				
African American	34	10%	0	0%	23	68%	2	6%	9	26%				
Asian	29	8%	5	17%	14	48%	3	10%	7	24%				
Multi, other	12	4%	0	0%	5	42%	3	25%	4	33%				
Hispanic/Latino	78	23%	11	14%	47	60%	3	4%	17	22%				
Dental or medical insurance											NE	0.9	0.02	<0.001
None	78	22%	7	9%	39	50%	14	18%	18	23%				
Yes - orthodontics and SX not covered	87	25%	12	14%	39	45%	8	9%	28	32%				
Yes - orthodontics covered, SX not covered	93	27%	16	17%	45	48%	8	9%	24	26%				
Yes - SX covered[6]	87	25%	0	0%	23	26%	5	6%	59	68%				

			Treatment category[1]								Cluster adjusted[4] p-values			
	ALL (N=345)		Aligners only (N=35)		Fixed appliances (N=146)		Temporary Anchorage Devices (N=35)		Orthognathic surgery (N=129)		ALN vs. FA	FA vs. TADs	TADs vs SX	SX: yes/no
Patient demographics	**N**	**Col %[2]**	**N**	**Row[3] %**	**N**	**Row[3] %**	**N**	**Row[3] %**	**N**	**Row[3] %**	**p**	**p**	**p**	**p**
Education level											0.07	NE	0.8	0.9
High school/GED or less	71	21%	7	10%	32	45%	7	10%	25	35%				
Some college/AD	109	32%	5	5%	51	48%	12	11%	41	38%				
Bachelors degree	105	31%	14	13%	40	38%	9	9%	42	40%				
Graduate degfree	57	17%	9	16%	20	35%	7	12%	21	37%				
											0.07	0.4	0.98	0.8
Less than bachelor's degree	180	53%	12	7%	83	46%	19	11%	66	37%				
Bachelor degree or higher	162	47%	23	14%	60	37%	16	10%	63	39%				
Prior orthodontic treatment											0.06	0.9	0.07	0.6
No	210	61%	17	8%	101	48%	15	7%	77	37%				
Yes	134	39%	18	13%	45	34%	20	15%	51	38%				

[1] Treatment categories are mutually exclusive (see Table 1); 2 are excluded as none of the 4 primary treatments above were recommended

[2] Overall column percent (denominator=345); columns not summing to 100 are due to rounding

[3] Row %: Percent of specified treatment within category of patient demgraphic characteristic

[4] Adjusted for patient clustering within practitioner using generalized estimating equations

[5] NE: Not estimable

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Table 4.

Patient dentofacial characteristics according to most ideal treatment recommendation category

			Treatment category[1]								Cluster adjusted[4] p-values			
	ALL (N=345)		Aligners only (N=35)		Fixed appliances (N=146)		Temporary Anchorage Devices (N=35)		Orthognathic surgery (N=129)		ALN vs. FA	FA vs. TADs	TADs vs SX	SX: yes/no
Patient dentofacial characteristics	**N**	**Col %[2]**	**N**	**Row[3] %**	**N**	**Row[3] %**	**N**	**Row[3] %**	**N**	**Row[3] %**	**p**	**p**	**p**	**p**
Profile											0.3	NE	0.2	0.3
Convex	187	54%	19	10%	76	41%	18	10%	74	40%				
Straight	129	37%	15	12%	56	43%	16	12%	42	33%				
Concave	29	8%	1	3%	14	48%	1	3%	13	45%				
Molar class (severest of right/left)											0.8	0.3	0.13	<0.001
I: up to half cusp Class II or Class III	142	41%	22	15%	75	53%	15	11%	30	21%				
II: Half cusp or more Class II	106	31%	7	7%	26	24%	12	11%	61	58%				
III: Half cusp or more Class III	95	28%	6	6%	43	45%	8	8%	38	40%				
Arch length (severest of maxillary or mandibular)											0.2	NE	NE	0.5
No crowding	70	20%	7	10%	31	44%	8	11%	24	34%				
Mild crowding (1–3mm)	122	35%	15	12%	47	39%	16	13%	44	36%				
Moderate crowding (4–6mm)	106	31%	7	7%	45	42%	11	10%	43	41%				
Severe crowding (>6mm)	47	14%	6	13%	23	49%	0	0%	18	38%				
Posterior crossbiite											0.7	0.4	0.008	<0.001
None	201	58%	25	12%	105	52%	22	11%	49	24%				
Unilateral	68	20%	7	10%	21	31%	8	12%	32	47%				
Bilateral	76	22%	3	4%	20	26%	5	7%	48	63%				
Facial pattern											0.2	0.8	0.09	<0.001
High angle	202	59%	21	10%	64	32%	20	10%	97	48%				
Normal	123	36%	13	11%	69	56%	13	11%	28	23%				
Low angle	19	6%	1	5%	13	68%	2	11%	3	16%				

			Treatment category[1]								Cluster adjusted[4] p-values			
	ALL (N=345)		Aligners only (N=35)		Fixed appliances (N=146)		Temporary Anchorage Devices (N=35)		Orthognathic surgery (N=129)		ALN vs. FA	FA vs. TADs	TADs vs SX	SX: yes/no
Patient dentofacial characteristics	**N**	**Col %[2]**	**N**	**Row[3] %**	**N**	**Row[3] %**	**N**	**Row[3] %**	**N**	**Row[3] %**	**p**	**p**	**p**	**p**
Patient habits														
Tongue thrust											0.2	0.09	0.8	0.2
No	237	69%	20	8%	97	41%	25	11%	95	40%				
Yes	108	31%	15	14%	49	45%	10	9%	34	31%				
Tongue posture											0.03	0.4	0.2	0.3
No	261	74%	21	8%	115	44%	24	9%	101	39%				
Yes	84	26%	14	17%	31	37%	11	13%	28	33%				
Digit											0.10	NE	0.6	0.5
No	319	92%	32	10%	132	41%	34	11%	121	38%				
Yes	26	8%	3	12%	14	54%	1	4%	8	31%				
Function/biting/bruxing											0.4	0.4	0.2	0.5
No	330	96%	32	10%	144	44%	32	10%	122	37%				
Yes	15	4%	3	20%	2	13%	3	20%	7	47%				
AOB severity index											0.7	0.8	0.03	<0.001
1–3	111	32%	10	9%	61	55%	15	14%	25	22%				
4–6	234	68%	25	11%	85	36%	20	9%	104	44%				

[1] Treatment categories are mutually exclusive (see Table 1); 2 are excluded as none of the 4 primary treatments above were recommended

[2] Overall column percent (denominator=345); columns not summing to 100 are due to rounding

[3] Row %: Percent of specified treatment within category of patient dentofacial characteristic

[4] Adjusted for patient clustering within practitioner using generalized estimating equations

[5] NE: Not estimable

Table 5.

Cephalogram (CEPH) measures according to most ideal treatment recommendation category

Table 5A. Mean CEPH measures

			Treatment category[1]								
	ALL (N=345)		Aligners only (N=35, 10%)		Fixed appliances (N=146, 42%)		TADs (N=35, 10%)		Orthognathic surgery (N=129, 37%)		Cluster adjusted
CEPH Measure	**Mean**	**(sd)**	**Mean**	**(sd)**	**Mean**	**(sd)**	**Mean**	**(sd)**	**Mean**	**(sd)**	**p**
ANB: Maxilla to mandible	3.2	(3.1)	3.5	(3.0)	3.2	(2.8)	2.9	(2.6)	3.4	(3.6)	0.5
MPSN: Mandibular plane angle	38.8	(7.2)	38.9	(7.4)	36.6	(6.5)	38.1	(7.7)	41.5	(7.0)	<0.001
PFHmm: Ratio posterior to anterior facial height	46.2	(6.0)	45.1	(4.8)	47.2	(6.3)	47.2	(4.8)	45.3	(6.0)	0.11
U1 degree	25.6	(8.3)	25.3	(7.6)	27.5	(8.4)	24.2	(8.0)	24.0	(8.1)	0.052
L1 degree	31.1	(8.3)	30.8	(6.4)	33.4	(8.5)	27.6	(6.9)	29.6	(8.3)	0.004
IMPA (MN incisor angulation to MP)	94.9	(8.8)	95.3	(6.6)	98.2	(8.4)	92.5	(7.8)	91.7	(8.6)	<0.001
Overbite (mm)	−2.4	(2.2)	−2.1	(1.6)	−2.2	(2.0)	−1.5	(1.8)	−3.0	(2.4)	0.009
Overjet (mm)	3.2	(2.7)	3.6	(2.0)	3.1	(2.5)	3.4	(2.0)	3.2	(3.2)	0.9

Table 5B. Associations of CEPH measures with most ideal treatment recommendation category

	Cluster adjusted[2] Odds Ratios (OR) and p-values							
	ALN vs FA		FA vs TADs		TADs vs SX		SX: yes/no	
CEPH Measure	**OR**	**p**	**OR**	**p**	**OR**	**p**	**OR**	**p**
ANB: Maxilla to mandible	0.97	0.7	1.05	0.3	0.96	0.4	1.02	0.6
MPSN: Mandibular plane angle	1.02	0.3	0.96	0.2	0.93	**0.03**	1.09	**<0.001**
PFHmm: Ratio posterior to anterior facial height	0.96	0.2	1.02	0.4	1.06	**0.09**	0.96	**0.06**
U1 degree	0.98	0.5	1.05	**0.01**	1.00	0.99	0.96	**0.02**
L1 degree	0.96	**0.07**	1.12	**<0.001**	0.97	0.3	0.97	**0.04**
IMPA (MN incisor angulation to MP)	0.97	0.16	1.11	**0.002**	1.01	0.6	0.93	**<0.001**
Overbite (mm)	1.12	0.3	0.80	**0.015**	1.46	**<0.001**	0.82	**<0.001**
Overjet (mm)	1.01	0.9	1.00	0.98	1.01	0.8	0.98	0.7

[1] Treatment categories are mutually exclusive (see Table 1); 2 are excluded as none of the 4 primary treatments above were recommended

[2] Adjusted for patient clustering within practitioner using generalized estimating equations

Table 6.

Distribution of 345 patients according to their most ideal treatment recommendation category[1] and whether extractions were recommended.

		Recommend extractions						
	ALL	Any		Non-molar				
				All		Exclude 14 patients missing 4 premolars		
	N	N	Row %	N	Row %	All	N	Row %
ALL:	345	90		67		331	67	
Main treatment category[1]								
Aligners	35	3	9%	2	6%	35	2	6%
Fixed appliances	146	53	36%	44	30%	139	44	32%
Temporary Anchorage Devices	35	7	20%	3	9%	31	3	10%
Orthognathic surgery	129	27	21%	18	14%	126	18	14%
cluster adjusted p-values		*p=0.01*		*p=0.003*			*p=0.004*	
Prior orthodontic treatment								
No	210	70	33%	53	25%	208	53	25%
Yes	134	20	15%	14	10%	122	14	11%
cluster adjusted p-values		*p=0.002*		*p=0.006*			*p=0.01*	

[1] Two patients were not recommended any of the 4 primary treatments of interest, and were thus excluded from analysis

P-values adjusted for patient clustering within practition using generalized estimating equations

Table 7A.

Recommending aligners versus fixed appliances (no TADs or Surgery): 35 vs 142 (total of 177)
Excludes 4 patients recommended aligners and braces

	Individual		Final model		
Characteristic	**OR**	**P**	**OR**	**95% CI**	**P**
Practitioner female	3.6	0.059	3.5	1.1 – 11.3	0.058
Pt: Caucasian or Asian vs African American or Hispanic/Latino	2.8	0.006	2.8	1.5 – 5.2	0.009
Patient education: BS or higher	1.5	0.07	x	x	x
Prior orthodontic treatment	1.8	0.06	x	x	x
Habit: Tongue posture	2.5	0.03	2.4	1.2 – 4.6	0.04
L1 degree	0.96	0.07	x	x	x
Recommend extraction	0.4	0.02	x	x	x

Table 7B.

Recommending Fixed appliances alone versus fixed appliances and TADS (no Surgery): 146 vs 29 (total of 175)

	Individual		Final model		
Characteristic	**OR**	**P**	**OR**	**95% CI**	**P**
Academic practice	0.2	0.01	0.2	0.06 – 0.95	0.03
Patient: African American or Hispanic/Latino	4.8	0.001	3.6	1.4 – 8.9	0.02
Prior orthodontic treatment	0.3	0.007	x	x	x
Habit: Digit	5.0	0.01	x	x	x
U1 degree	1.05	0.01	1.05	1.00 −1.10	0.03
L1 degree	1.12	<0.001	1.10	1.03 −1.17	0.003
L1MPdeg	1.11	0.002	x	x	x
Overbite (mm)	0.80	0.016	x	x	x
Recommend extraction	4.8	0.01	x	x	x

Table 7C.

Recommending TADs versus Orthognathic Surgery: 35 vs 127 (total of 162)
Excludes 2 patients recommended TADs and surgery

	Individual		Final model		
Characteristic	**OR**	**P**	**OR**	**95% CI**	**P**
No insurance coverage for SX	3.4	0.02	2.7	1.2 – 6.5	0.046
Prior orthodontic treatment	2.0	0.07	x	x	x
Molar Class 1 (vs 2 or 3)	2.2	0.045	2.4	1.1 – 5.1	0.061
No posterior crossbite	3.5	0.002	2.2	1.0 – 5.0	0.054
Normal or low angle facial pattern	2.9	0.03	2.2	1.0 – 4.6	0.099
AOB score 4–6 (vs 1–3)	0.3	0.3	x	x	x
MPSN (Mandibular plane angle)	0.93	0.03	x	x	x
PFHmm	1.06	0.09	x	x	x
Overbite (mm)	1.47	<0.001	1.4	1.1 – 1.8	<0.001

Table 7D.

Recommending Orthognathic Surgery (yes/no): 127 vs 216 (total of 343)
Excludes 2 patients recommended TADs and surgery

	Individual		Final model		
Characteristic	**OR**	**P**	**OR**	**95% CI**	**P**
DDS Caucasian or Asian	4.3	0.02	5.8	1.7 – 20.1	0.02
Patient: Caucasian	2.5	0.002	x	x	x
Insurance covers SX	4.8	<0.001	3.8	1.9 – 7.9	<0.001
Molar Class 2 or 3	3.3	<0.001	3.4	1.8 – 6.1	<0.001
Any posterior crossbite	3.9	<0.001	3.6	2.1 – 6.3	<0.001
Steep facial angle	4.1	<0.001	x	x	x
AOB Score 4–6 vs 1–3	3.1	<0.001	x	x	x
MPSN (Mandibular plane angle)	1.10	<0.001	1.09	1.04 – 1.14	<0.001
U1 degree	0.96	0.02	x	x	x
L1 degree	0.97	0.04	x	x	x
L1MP degree	0.93	<0.001	x	x	x
Overbite (mm)	0.82	<0.001	0.87	0.76 – 0.99	0.04

Table 7E.

Recommending extractions of non-molars: 67 vs 264 (total of 331)
Excludes 14 patients missing 4 premolars

	Individual		Final model		
Characteristic	**OR**	**P**	**OR**	**95% CI**	**P**
Patient age (years)	0.97	0.03	0.96	0.93 – 0.99	0.01
Prior orthodontic treatment	0.44	0.01	x	x	x
Convex profile	2.4	0.008	x	x	x
Moderate/severe crowding	5.1	<0.001	8.0	4.3 – 14.8	<0.001
None/unilateral posterior crossbite vs bilateral	2.6	0.02	x	x	x
Tongue posture	0.39	0.01	0.40	0.17 – 0.96	0.02
ANB: Maxilla to mandible	1.13	0.01	x	x	x
MPSN (Mandibular plane angle)	1.04	0.03	x	x	x
L1 degree	1.05	0.007	1.09	1.05 – 1.13	<0.001

All associations (OR) and p-values are adjusted for clustering of patients within practices using generalized estimating equations (GEE). They were implemented using PROC GENMOD in SAS.

Individual' column ORs and p-values are adjusted only for clustering of patients within practitioners.

x: characteristic was not lower than either 10% or 5%, depending on comparisons, and was thus not retained in the model.