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Extraction Frequencies at a University Orthodontic Clinic in the 21st Century: Demographic and Diagnostic Factors Affecting the Likelihood of Extraction

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Abstract

Introduction—The aims of this study were 1) to report contemporary orthodontic extraction frequencies at a university center and 2) to investigate what patient-related factors might influence the likelihood of extraction.

Methods—The records of 2,184 consecutive patients treated at the University of North Carolina from 2000 – 2011 were analyzed. Year by year rates for overall orthodontic extractions and for extraction of four first premolars were calculated. Logistic regression, adjusting for all recorded patient risk factors for extraction, was used to examine both the changes in extraction frequencies over time and the influence of individual patient factors on the odds of extraction.

Results—A small linear decrease in orthodontic extraction frequency overall (OR=0.91; 95%CI 0.88, 0.95) and in extraction of four first premolars (OR=0.95; 95%CI 0.90, 0.99) was seen. The overall extraction rate was 37.4% in 2000 and fell just below 25% from 2006 onward. Four first

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premolar extraction rates ranged from 8.9% to 16.5%. Extractions were significantly more likely as crowding and overjet increased (OR=1.2; 95%CI 1.14, 1.25; OR=1.1; 95%CI 1.07, 1.19), as overbite decreased (OR=0.8; 95%CI 0.77, 0.89), in the presence of Class II dental or skeletal relationships (OR=1.5; 95%CI 1.12, 2.05; OR=1.4; 95%CI 1.04, 1.85), and for non-Caucasians (OR=3.0; 95%CI 2.2, 4.06 for “Other races”; OR=4.1, 95%CI 3.03, 5.66 for African-Americans).

Conclusions—Extractions were just as likely to be associated with Class II dental and skeletal problems and with open-bite problems as with crowding alone.

INTRODUCTION

The extraction of permanent teeth for orthodontic reasons has been a topic hotly debated in the past[1] and continues to be of interest within the specialty of Orthodontics. For the clinician, it is important, regardless of practice philosophy, to have an understanding of contemporary rates of extraction as an adjunct to comprehensive orthodontic treatment.

Historically, reported extraction rates have varied widely from less than 25% of patients to more than 80%[1-5]. Data derived from surveys of practicing orthodontists have been shown to be subject to significant inaccuracies[5]. For this reason, data generated from institutions where a large number of patients are treated using a variety of treatment philosophies are preferred because they can provide more meaningful epidemiologic information.

In the early 1990's, Proffit summarized extraction rates over a forty year period at the University of North Carolina. He found that the rate of extraction increased from 30% in 1953 to a peak of 76% in 1968 before falling to nearly 28% again in 1993[1]. Importantly, most of the fluctuation in these rates was apparently driven by a change in the frequency of extraction of all four first premolars, with other extraction patterns showing less change. The changes in four first premolar extractions were attributed to evolving orthodontic philosophy regarding the stability of alignment after arch expansion, to advances in bonded rather than banded orthodontic appliances, and to the esthetic impact of incisor position on the soft-tissues of the face.

More recently, Janson and co-workers have reported the experience of a Brazilian university with changes in extraction rates over time[2]. They found that over a thirty-five year period, the extraction rate fell from nearly 86% of all patients in 1973 to 46% in 2007, with a concurrent downward trend in the rate of four first premolar extractions over the same time period as well. The authors theorize that the decrease in extraction rate was due to variables similar to those Proffit discussed, as well as a fear of a connection between tooth extraction and temporomandibular joint dysfunction and also changes in the use of growth modification, interproximal reduction, and maxillary expansion.

Both of these institution-based studies used a model by which the outcome (extraction) was the focus of the investigation. In this way, extraction patterns were used to generate insight as to trends in treatment style. For example, the extraction of two premolars in a single arch to camouflage an anterior-posterior issue versus the extraction of four premolars for crowding/protrusion. Indeed, treatment strategy, including the extraction pattern and appliances or methods used, is one very important component in understanding the current

use of tooth extraction in orthodontics. The present study, however, focuses not on appliances or techniques as an explanation for extraction frequency, but instead on patient-related factors alone.

Given the breadth of individual orthodontic practice styles today, it is important to understand extraction frequencies as a function of patient demographic and diagnostic parameters that might influence the decision to extract (*e.g.* age, race, crowding, overjet, overbite). Up to this point, no institution-derived data to this effect have been widely published.

An understanding of what patient-related variables might be most closely associated with an increased odds of orthodontic extraction might aid the modern clinician in understanding his or her use of diagnostic information to make individual treatment decisions. This type of information might be of particular use in orthodontic training programs to aid future generations of orthodontists in gaining a better perspective on the need for orthodontic extractions – as well the need for the skills to manage extraction cases. Additionally, this information might improve patient communication because often patients would like a better understanding of how the treatment recommended for them compares with treatment frequently recommended for other patients.

The aims of this investigation were 1) to report extraction frequencies at a university center in the beginning of the 21st century and 2) to use an epidemiologic model to investigate what patient demographic or diagnostic factors might influence the likelihood of extraction in the contemporary practice of orthodontics.

To address these aims, the records of 2,184 patients treated in the Department of Orthodontics at the University of North Carolina (UNC) from 2000 – 2011 were analyzed.

MATERIAL AND METHODS

The Graduate Clinic within the Department of Orthodontics at the University of North Carolina provides orthodontic and dentofacial orthopedic care using a resident-attending model. For each patient treated, pre-treatment patient-related variables are recorded using a standardized format and stored in a centralized digital database. Among the demographic and diagnostic variables recorded for each patient are a number of potential factors that might influence the likelihood of orthodontic tooth extraction.

All characteristics meaningfully recorded for each patient that could be a risk factor for orthodontic extraction are reported in Table I. Consecutive patients were selected to be included in the sample as participants in this study if their comprehensive orthodontic treatment began no earlier than January 1, 2000 and ended by December 31, 2011 (2011 was the final year for which data were available). Inclusion criteria were that the participant must have complete pre-treatment and post-treatment data present in the digital database. The outcome measured was extraction of teeth for orthodontic purposes, other than third molars. Extractions of primary teeth were not included. Since the study was designed to investigate patient-related factors (rather than treatment-related factors) using an epidemiologic approach, all extractions of permanent teeth for orthodontic purposes, including those

performed during a first phase of early treatment or in conjunction with growth modification or orthognathic surgery were included. Approval for this study was given by the Institutional Review Board before data were gathered (IRB#132184).

In addition to descriptive statistics for the participant characteristics that might have an impact on risk for extraction, year by year extraction rates overall and for four first premolars in combination were calculated. Third molar extractions were not included in any data or analyses. Logistic regression was used to analyze the trend in extraction rate over time. Multivariate analyses were used to compare participant characteristics at five year intervals. Across the entire sample, logistic regression, adjusting for all possible risk factors for extraction found in Table I, was used to examine the influence of individual characteristics on the odds for extraction of teeth for orthodontic purposes. Results are reported as odds ratios with 95% confidence intervals as measures of variance. Odds ratios report associations in terms of the odds that a certain outcome (*e.g.* tooth extraction) will occur given a certain exposure (*e.g.* a Class II dental relationship). All analyses were 2-sided and conducted using SAS version 9.2 (SAS Inc., Cary, NC), with a level of statistical significance set at $p=0.05$.

RESULTS

Characteristics for the 2,184 participants included in the study are reported in Table I. Since these variables were not normally distributed, as determined by Kolmogorov-Smirnov tests, medians and interquartile ranges are reported.

Participant characteristics that might influence extraction frequency were compared at five year intervals (2000, 2005, and 2010) in Table I. There was a statistically significant difference in racial composition of participants across these time points ($p<0.001$), with a consistently decreasing proportion of Caucasian participants; there were more African-American participants in 2005 but more “Other” patients in 2010 (“Other” includes Asian, Hispanic, and Native American). Participant age showed significant differences across the years examined ($p<0.001$), with a small rise from 2000 to 2010. Similarly, the proportion of participants who exhibited at least one tooth with clinically apparent reduced attached gingiva (less than 1mm present) varied across these years ($p<0.001$). Initial curve of Spee also showed a statistically significant (but not clinically significant) difference across these years ($p=0.001$). These results confirm that participant characteristics that might influence extraction frequency did, in fact, vary over time.

Extraction rates by year may be found in Figure 1. Overall extraction frequency was at its highest point in 2000 at 37.4%, dropped to a low of 17.6% in 2005, and remained consistently just below 25% from 2006 – 2011. The frequency of four fist premolar extractions (included here for comparison to other reports rather than for detailed analysis) similarly reached a high value in 2000 at 16.5% but then remained relatively consistent just above 10%, ranging as low as 8.9% in 2006 and 2010 and as high as 13.4% in 2008.

To account for fluctuation in participant characteristics from year to year, a logistic regression model, adjusted for all the characteristics in Table I, showed that the odds of

extraction chronologically by year was 0.91overall and 0.95 for four first premolars (see Table II). In other words, when controlling for all of the factors in Table I that might vary year to year, there was a linear downward trend in the odds of extraction from 2000 to 2011. When the quadratic term was applied to the overall rate, there was no significant change in odds of extraction by year (see Table II). The quadratic term was tested since there was an apparent frequency drop at 2005 and then a subsequent increase. The non-significant result confirmed that the downward trend in extraction over time followed a linear path from 2000 to 2011, rather than a parabolic path as might be suggested by visual inspection of the data in Figure 1.

Logistic regression was further employed to explore the influence of participant characteristics in the overall study sample on the odds of extraction (Table III). Controlling for all other factors in Table I, the odds of extraction for African-American participant's was 4.1 times that of Caucasian patients (OR=4.1), while participants of other races had 3.0 times the odds of Caucasians (OR=3.0). Even when controlling for the risk factors in Table I, as Overjet (OR=1.1), maxillary crowding (OR=1.2), and mandibular crowding (OR=1.2) increased, so too did the odds of extraction. As overbite decreased (OR=0.8), the odds of extraction increased, even when controlling for other risk factors. Odds of extraction also increased with a Class II skeletal (OR=1.4) or dental (OR=1.5) relationship, considered separately and adjusted for the risk factors in Table I.

DISCUSSION

The extraction rates found in Figure 1 reflect the treatment of more than 2,000 patients from 2000 to 2011 using a variety of techniques and treatment philosophies espoused by twenty-five different attending orthodontists, the majority of whom were part-time clinical faculty and treated patients full-time in a private practice setting.

Overall, the demographic composition of the study participants (Table I) approximates that of the United States according to the 2010 Census[6], although females are slightly over-represented in our sample. As expected for patients who are actually seeking treatment, the proportions of participants in our sample with either Class II or Class III skeletal or dental problems were greater than those estimated in the general population[7]. Because a conscious effort is made to ensure that residents at UNC treat a variety of malocclusions, it may be possible that these proportions over-represent certain malocclusions when compared to patients treated in private practices across the US. For the purpose of examining the effect of diagnostic factors like Class II or Class III malocclusion on the likelihood for extraction, however, this variation in the sample is desirable. Similarly, the interquartile ranges reported for age, overjet, overbite, and crowding in the study sample (Table I) display variability that is likely to capture the full range of orthodontic patients that might be encountered in practice.

Not surprisingly, the diagnostic and demographic characteristics of the participants in the sample were not constant from year to year. Significant differences in factors at five year intervals were confirmed by the multivariate analyses summarized in Table I. In order to account for these fluctuations when exploring the trend in overall extraction frequency from

2000 to 2011, a logistic regression model was used that adjusted the odds of extraction for each year by all of the characteristics in Table I. When controlling for all of these factors, a linear downward trend was confirmed over the first decade of the 21st century (Table II), despite an obvious drop in extraction rate at 2005. Accordingly, the overall extraction frequency is best summarized as being highest at 37.4% in 2000 and then trending downward over the decade to a relatively consistent level near 25% from 2006 onward. These frequencies fall below the rates reported by Janson in Brazil over a similar time period ending in 2007[2].

It is interesting to note that from 1953 to 1993, the frequency of four first premolar extractions was reported as the prime determinant of the very large changes seen in the overall extraction rate at UNC[1], varying from as low as 10% to a peak of 50%. From 2000 to 2011, the rate of four first premolar extractions remained more consistent, showing a slight downward trend and ranging only from 8.9% to 16.5%.

Following the historic model at UNC of assessing extraction frequency at ten year intervals, the overall extraction rate in 2003 of 27.7% was almost identical to the rate of 28% found in 1993[1]. Similarly, the extraction rate of four fist premolars in 2003 was largely unchanged from ten years prior. In short, extraction rates at UNC in the 21st century appear to be somewhat of an extension of the trends reported a decade earlier.

With a large and varied sample, such as the one for this study, logistic regression can be used to estimate the odds of extraction for a participant with a given characteristic while controlling for the possible influence of other factors that might be confounders (*e.g.* What is the prevailing influence of crowding, when controlling for factors such as Angle Classification and overbite?).

Employing such a model revealed that, all else being equal, as crowding increased, so did the odds that teeth would be extracted (OR=1.2, see Table III). Although statistically significant, such a mild increase in odds suggested that crowding alone may not be a powerful diagnostic indicator for the likelihood of extraction. That statement seems to fit with the narrative involving tooth extraction over the historical course of orthodontics and with conclusions drawn more than twenty years ago[1]. When orthodontic extraction frequencies peaked in the 1960's, the prevailing reason appears to have been a concern for stability: space was required so that teeth might be aligned within the constraints of the bony dental arches[8, 9]. As the specialty evolved, the ability to modify growth and expand the maxillary arch orthopedically[10], the use of interproximal reduction of tooth mass[11], and the understanding that extraction does not guarantee stability of alignment[12] all de-emphasized the importance of crowding as a determinant for extraction. Extraction to eliminate crowding has further been re-evaluated based on the contemporary sensibility that facial esthetics and soft-tissue support may trump the need for space to have upright incisors within the arch[13]. In short, as reported here, the small increase in odds of extraction due to crowding alone reflects the modern orthodontic tenet that the decision to extract is more complex than crowding alone.

When controlling for the amount of crowding present in both arches, as well as for all of the other risk factors recorded for the sample, as overbite decreased, the odds of extraction increased (OR=0.8, see Table III). This small but statistically significant effect suggests that the use of extractions in modern orthodontics is influenced by the need to gain or maintain overbite. The use of extractions to control the vertical dimension is certainly an accepted contemporary treatment modality[14].

In the anterior-posterior dimension, as overjet increased, the odds of extraction increased (OR=1.1). Similarly, for participants who had a Class II skeletal or dental relationship, the odds of extraction was increased compared to Class I participants (OR=1.4, 1.5 respectively). Participants with a Class III skeletal or dental malocclusion were no more likely to have extractions than Class I participants. Together, these results suggest a trend in modern US orthodontics to use extractions to camouflage a Class II relationship more often than a Class III relationship. Importantly, these data align with a recently published report of patients undergoing surgical-orthodontic treatment from 2006-2010. That study found that the proportion of Class III patients undergoing surgical treatment had increased, while the proportion of surgical Class II patients had decreased compared to a time period ten years earlier[15].

An examination of the effect of race on the likelihood of extraction in this study offers an interesting perspective on the complex interplay between protrusion, esthetic evaluation, and the need for extractions. For African-American participants, the odds of extraction was significantly increased by four times when compared to Caucasian participants. For those in the “Other” category (primarily Asian, Hispanic, and Native American), the odds of extraction was three times greater.

Why were the odds of extraction so much higher in non-Caucasian participants? It is well-established that dental and labial protrusion is more prevalent in these groups[16-21]. Other factors that might affect the likelihood of extraction and might also be more prevalent in these groups (*e.g.* anterior open bite in African-Americans, Class III in Asians[7]) were controlled for by using the logistic regression model. Accordingly, the odds reflected here account for those differences. Since protrusion was not otherwise accounted for because it was not meaningfully measured in the sample, it is likely that the increased frequency of extraction was due to an increase in protrusion. It is important to point out the limitation that the retrospective data presented here can not definitively support that assumption, however, since neither hard-tissue (*e.g.* incisor inclination) nor soft-tissue (*e.g.* lip protrusion) measures of protrusion were recorded in an objective way across this large sample.

Contemporary orthodontic philosophy recognizes that the decision to extract for protrusion is a complex one – one that might certainly be affected by patient and practitioner demographics as well as differences in esthetic perceptions and treatment styles[22-24]. A plethora of cephalometrically-derived guidelines for diagnosing or correcting hard and / or soft-tissue measures of protrusion exist. The now well-established soft-tissue paradigm[13] suggests that an esthetic facial outcome might be a more subjective target, dictated by individual perception rather than cephalometric values. Accordingly, the “personal” decision as to whether protrusion exists, and warrants the extraction of teeth is a question that can not

be fully addressed by the investigation reported here. Future and on-going research is needed to more fully elucidate the effect of protrusion on the decision to extract.

Collectively these results suggest that extractions are just as likely to be needed for occlusal considerations, specifically for vertical control and in Class II patients, as to be needed for crowding. It also appears that, at least in this sample, extractions were significantly more likely in non-Caucasian groups.

The pressure to avoid tooth extraction as an adjunct to treatment is a recurring theme for the orthodontic profession, whether for real or perceived benefits in health or esthetics for the patient or for putative benefits in convenience or mechanical efficiency for the practitioner[4]. Just as this controversy is unlikely to find a quick resolution, it is perhaps equally unlikely that the ability to close extraction spaces is a skill that will soon become obsolete and no longer taught in orthodontic training programs.

An ongoing evaluation of extraction rates, as well as the myriad factors affecting the extraction decision (including non-patient-related factors such as treatment modality), will continue to be of real importance as both industry-directed and scientific innovations move the profession forward.

CONCLUSIONS

In a university setting during the first decade of the 21st Century:

1) Overall orthodontic extraction rates showed a mild decreasing trend, leveling near 25% after 2006.

2) The rate of extraction of four first premolars decreased slightly but remained just above 10%.

3) The odds of extraction increased with increasing crowding, increasing overjet, decreasing overbite, and the presence of a Class II dental or skeletal malocclusion. Extractions were just as likely to be associated with Class II dental and skeletal problems and with open-bite problems as with crowding alone.

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HIGHLIGHTS

- Overall orthodontic extraction rates showed a mild decreasing trend, leveling near 25% after 2006.
- The rate of extraction of four first premolars decreased slightly but remained just above 10%.
- The odds of extraction increased with increasing crowding, increasing overjet, decreasing overbite, and the presence of a Class II dental or skeletal malocclusion. Extractions were just as likely to be associated with Class II dental and skeletal problems and with open-bite problems as with crowding alone.
- Overall orthodontic extraction rate showed a mild decreasing trend from 2000 to 2006
- Overall extraction rate remained near 25% after 2006.
- Extraction of 4 first premolars decreased slightly but remained just above 10%.
- Extraction odds increased with increasing crowding or overjet
- Extraction odds increased with decreasing overbite or presence of Class II malocclusion.

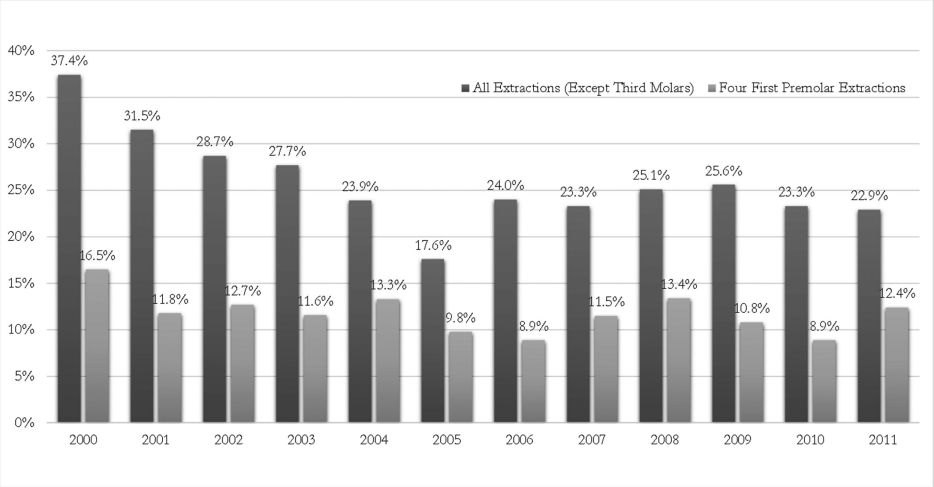

Figure 1.
Extraction Rates by Year

Table I

Participant Characteristics Overall and for Years 2000, 2005, and 2010

Characteristic	Overall Median (IQR*) or % n=2184	Year 2000 Median (IQR) or % n=115	Year 2005 Median (IQR) or % n=102	Year 2010 Median (IQR) or % n=326	p-value**
Gender					
% Female	58.0	56.0	52.9	58.3	0.624
% Male	42.0	44.0	47.1	41.7	
Race					
% Caucasian	68.6	82.3	68.6	63.5	<0.001
% African-American	16.4	11.5	17.6	15.0	
% Other	15.0	6.2	13.7	21.5	
Age at Start of Treatment (years)	14.1 (12.7 - 16.8)	13.4 (12.2-15.5)	14.1 (12.4-16.2)	14.5 (13.0-19.2)	<0.001
% With Reduced Gingival					
Attachment Present	34.4	38.3	50.0	20.0	<0.001
Initial Overjet (mm)	4.0 (2.0-5.0)	4.0 (3.0-6.0)	3.0 (3.0-5.0)	4.0 (2.0-5.0)	0.264
Initial Maxillary Crowding (mm)	2.0 (0.0 -4.0)	2.0 (0.0-5.0)	2.0 (0.0-5.0)	2.0 (0.0-5.0)	0.823
Initial Mandibular Crowding (mm)	3.0 (0.0-5.0)	2.0 (0.0-5.0)	2.0 (0.0-4.3)	3.0 (1.0-5.0)	0.214
Initial Curve of Spee (mm)	2.0 (1.0-3.0)	2.0 (2.0-3.0)	2.0 (2.0-3.0)	2.0 (1.0-3.0)	0.001
Initial Overbite	3.0 (2.0-5.0)	4.0 (2.0-5.0)	3.0 (2.0-5.0)	3.0 (2.0-5.0)	0.186
Skeletal A-P Relationship					
% Class I	47.0	44.7	47.1	50.9	0.792
% Class II	38.9	36.8	37.3	34.0	
% Class III	14.1	18.4	15.7	15.0	
Angle Classification					
% Class I	47.1	49.1	54.9	42.3	0.162
% Class II	43.4	42.0	33.3	46.3	
% Class III	9.5	8.9	11.8	11.6	

*IQR = Inter-Quartile Range

**Level of statistical significance set to p=0.05; Chi-Square or Kruskal-Wallis to compare Years 2000, 2005, and 2010

Table II

Odds of Extraction by Year, Adjusted for Potential Risk Factors in Table I*

	Odds Ratio (OR)	95% Confidence Interval (95% CI)	p-value
Overall Extractions by Year	0.91	(0.88, 0.95)	<0.001
Overall Extractions by Year (Quadratic)	1.0	(1.00, 10.2)	0.066
Four First Premolar Extractions by Year	0.95	(0.90, 0.99)	0.017

* Level of statistical significance set to p=0.05, Odds based on a logistic regression model for the likelihood of extraction, adjusted for all participant characteristics found in Table I

Table III

Odds of Extraction by Participant Characteristic, Adjusted for Potential Risk Factors in Table I*

Characteristic	Odds Ratio (OR)	95% Confidence Interval (95% CI)	p-value
Gender			
Female	Reference		
Male	1.2	(0.96, 1.52)	0.101
Race			
Caucasian	Reference		
African-American	4.1	(3.03, 5.66)	<0.001
Other	3.0	(2.2, 4.06)	<0.001
Age at Start of Treatment (years)	1.0	(1.00, 1.02)	0.022
Reduced Gingival Attachment Present	1.1	(0.88, 1.43)	0.347
Initial Overjet	1.1	(1.07, 1.19)	<0.001
Initial Maxillary Crowding	1.2	(1.14, 1.25)	<0.001
Initial Mandibular Crowding	1.2	(1.18, 1.30)	<0.001
Initial Curve of Spee	1.0	(0.92, 1.17)	0.53
Initial Overbite	0.8	(0.77, 0.89)	<0.001
Skeletal A-P Relationship			
Class I	Reference		
Class II	1.4	(1.04, 1.85)	0.027
Class III	1.0	(0.64, 1.46)	0.884
Angle Classification			
Class I	Reference		
Class II	1.5	(1.12, 2.05)	0.007
Class III	1.1	(0.70, 1.78)	0.644

*Level of statistical significance set to p=0.05, Odds based on a logistic regression model for the likelihood of extraction, adjusted for all participant characteristics found in Table I