CURRICULUM VITAE

NAME: Sarah Pavon Groy, DMD

CONTACT: sarah.pavon@umaryland.edu

COLLEGIATE INSTITUTIONS ATTENDED:

2011 – Present	University of Maryland, Department of Orthodontics Candidate - Certificate in Orthodontics and M.S. in Oral Biology, Chief Resident
2007 – 2011	Temple University Kornberg School of Dentistry, D.M.D., May 2011; Summa Cum Laude
2000 - 2004	College of William and Mary, BA English Literature

PROFESSIONAL MEMBERSHIPS:

2011—Present	American Association of Orthodontists (AAO)
2011—Present	Mid-Atlantic Society of Orthodontists (MASO)
2007—Present	American Dental Association (ADA)

AWARDS AND HONORS:

2011	American Association of Orthodontists – Award for Exceptional Interest in the Development of the Oro-Facial Complex
2011	Omicron Kappa Upsilon Honorary Dental Society
2011	R. Ralph Bresler M.D. Pediatric Dentistry Award
2011	Stomatognathic Honor Society
2011	Dental Anesthesia Honor Society

LICENSURE AND CERTIFICATION:

2011	North East Regional Board (NERB) Certified
2010 – Present	Invisalign Certified

ABSTRACT

Title of Thesis: An In-Depth Analysis of Borderline Class I Malocclusions in Caucasian Patients at the University of Maryland

Sarah Pavon Groy, Master of Science, 2014

Thesis Directed by: Robert E. Williams, DMD, MA
Clinical Associate Professor
Department of Orthodontics, University of Maryland, Baltimore

Problem: To determine if a group of experienced clinicians determines there to be equal numbers of extraction and nonextraction treatments planned when evaluating borderline Class I malocclusions in Caucasian patients, and second, to determine the variables that are most important in the diagnosis and evidence-based treatment planning of these cases.

Methods: All Caucasian patients treated in the University of Maryland, Baltimore Orthodontic Graduate Clinic having completed initial orthodontic records over a three-year period were evaluated for the presence of a borderline Class I Malocclusion. Of the initial 180 subjects, 15 were statistically determined to be borderline and were subsequently subjected to analysis by 11 orthodontic faculty members. The cases were then evaluated for those variables determined to be indicative of borderline Class I malocclusions in Caucasian patients based on stepwise forward logistic regression.

Results: There was no significant difference between the treatment plan recommended and the 50/50 treatment expected for borderline cases (X^2=0.055, p = 0.8153), although extraction treatment was slightly more likely to be chosen by those surveyed (50.9%) than non-extraction treatment (49.1%). As determined through logistic regression, the four most significant variables were the mandibular intercanine measurement and maxillary crowding, (both study model variables), followed by the cephalometric Z-angle and the upper lip to E-plane measurement.

Conclusions: The results of the first stage of this study, which evaluated the percentage of extraction and non-extraction cases planned by faculty members when evaluating borderline Class I malocclusions in Caucasian patients, found that there was no significant difference in the percentage of extraction and non- extraction treatments planned The most common extraction pattern was the extraction of all four first bicuspids (44.1%). The results of the second stage of the study identified cephalometric and study model variables that were indicators of borderline Class I malocclusions in Caucasian patients. The four variables with the highest B value significance levels were identified through logistic regression to be the mandibular intercanine width and maxillary arch crowding, followed by the Z-angle and the upper lip to E-plane measurement.

An In-Depth Analysis of Borderline Class I Malocclusions in Caucasian Patients at the University of Maryland

by
Sarah Pavon Groy

Thesis submitted to the Faculty of the Graduate School
of the University of Maryland, Baltimore in partial fulfillment
of the requirements for the degree of
Master of Science
2014

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

I. INTRODUCTION

According to the clinical practice guidelines set forth by the American Associaition of Orthodontists, the major responsibilities of orthodontic practice include the "diagnosis, prevention, interception, and treatment of all forms of malocclusion of the teeth and associated alterations of their surrounding structures; the design, application, and control of functional and corrective appliances; and the guidance of the dentition and its supporting structures to attain and maintain optimal occlusal relations and physiologic and esthetic harmony among facial and cranial structures".[1] While most practicing orthodontists would likely agree that the attainment of optimal occlusion and esthetic craniofacial harmony is a goal sought for each patient encountered in their practice, far fewer would likely agree on the best way to attain that goal.

More specifically, there is currently a renewed interest on the impact that extraction or nonextraction treatment has on the profile, face, and smile. Although the percentage of patients with "dished-in" profiles after extraction treatment has been found to be very small, the detrimental effect of tooth extraction on the facial profile is a common belief held by many orthodontists. This view has led to reduced extraction rates in recent years and to the increasing tendency to use non-extraction techniques, such as expansion or interproximal reduction via air rotor stripping.[2] In fact, Proffit carried out a 40-year review of extraction frequencies at the University of North Carolina and found that the number of patients who had first premolars extracted increased from 10% in 1953 to 50% in 1963. The percentage then remained at 35%-45% until the early 1980's, and then gradually declined back to 10% in the 1990's.[3]

In spite of the debate surrounding extractions, the ideal treatment plan for a straightforward Class I malocclusion may often be fairly easily defined using specific criteria and measurements, such as the presence of severe crowding or excessive protrusion. However, the debate reappears when dealing with "borderline" cases, which by definition do not direct themselves to a clear-cut treatment plan among a group of experienced practitioners. The majority of studies comparing the results of extraction and nonextraction treatment do not assure through use of specific exclusion criteria that the cases are borderline, or equally susceptible to either treatment technique at the outset of treatment.

This study will attempt to avoid potential susceptibility bias through the use of a discriminant analysis. This study follows a previous study at the University of Maryland regarding borderline Class I malocclusions in black patients, and it will seek to evaluate the percentage of extraction and non-extraction cases as treatment planned by faculty members when evaluating borderline Class I malocclusions in Caucasian patients. The second part of the study will seek to identify any cephalometric or study model variables that statistically serve as indicators of borderline Class I malocclusions in Caucasian patients. The need to "clearly indicate those variables that identify borderline Class I malocclusions could not be more apparent. It is this knowledge that will help provide a scientific basis to the art of orthodontic treatment planning and in turn, strengthen our stance as orthodontists within the scientific community".[4]

II. LITERATURE REVIEW

Cephalometric Analysis

Before the introduction of cephalometric radiography, orthodontic decision-making was primarily based on observation of the patient's facial form and dental relationships. Although the original purpose of cephalometrics was for research on growth patterns of the craniofacial complex, cephalometric films came to be recognized as valuable tools in evaluating dentofacial proportions and clarifying the anatomic basis for malocclusion. In fact, the clinical practice guidelines of the AAO assert that pretreatment diagnostic records for comprehensive orthodontic treatment should include extra and intraoral images, dental casts or digital models, intraoral and/or panoramic radiographs, and cephalometric radiographs (although three-dimensional cone-beam computer tomography may be used as an alternate imaging source)[5]. Cephalometric radiographs permit evaluation of the size, shape, and positions of the craniofacial structures and dentition, and aid in the identification of skeletal anomalies or pathology.

Routine use of cephalometrics in the 1950's and its elevation to a standard of care in the years following, naturally led to the creation of analyses to aid the orthodontist in diagnosing, treatment planning, and subsequently, analyzing treatment.[6] Some of the better-known analyses include those of Downs (1948, 1952), Steiner (1953, 1959, 1960), and Tweed (1954), and the Wits appraisal from Jacobson (1975).[7] Steiner's 1953 article "Cephalometrics for you and me," and his subsequent articles popularized his Steiner

Analysis, which is the foundation of the Maryland Analysis at the University of Maryland Department of Orthodontics.[8]

Multiple studies have shown that the soft tissue covering the teeth and bones can vary so greatly that the dentoskeletal pattern may be insufficient in evaluating facial disharmony. McNamara also notes that for each individual, infinite combinations of features are possible to arrive at a face that is well balanced and with an occlusal relationship that is ideal. Therefore, "the purpose of establishing cephalometric norms, should not be to create 'targets' for individual treatment but to have guides for the clinical assessment of the patient".[9]

Considerations in Treatment of a Borderline Malocclusion

In light of the controversy surrounding extractions, an important question to be answered, especially for borderline cases, is whether treatment will result in undesirable profile changes. If crowding dictates the need for extraction, facial balance may influence which teeth are extracted, the type of anchorage required, and how the spaces will be closed.[10]

In borderline patients with good facial balance and moderate crowding, treatment considerations include how to resolve the crowding without creating instability or adversely affecting the facial profile. For instance, nonextraction treatment may be esthetically acceptable for Class I borderline patients with an orthognathic facial profile and moderate dental crowding, while patients with protrusive lips might benefit more from extraction therapy. Ackerman and Proffit take this concept a step further by stating

that for patients with a large nose and chin, protraction of the incisors is a better treatment choice than retraction.[11] Therefore, orthodontic treatment mechanics and anchorage preparation take on utmost importance when treating borderline malocclusions.

Race-Specific Facial Analysis

Racial and gender characteristics must be kept in mind for hard and soft tissue measurements when treatment planning to provide the most successful and esthetic result. Treatment planning for borderline Caucasian patients may differ from that of other races then with regard to facial esthetics, most specifically the acceptable degree of lip protrusion and the degree of convexity of the facial profile. Scott and Johnston showed that panels composed of different races differ in their estimate of when a patient would benefit from extractions in order to reduce profile protrusion. They sought to determine the degree of lip protrusion at which the retraction following extraction would be seen by panelists (orthodontists and laypersons) as beneficial to facial esthetics. They found that white panelists preferred to extract to improve the patient's profile when the lower lip was at least 2 mm in front of Ricketts' E-plane, while black panelists determined this threshold point to be more forward, at 4 mm.[12] In contrast, the study of Bowman and Johnston, which used Caucasian subjects, found the threshold points to be well behind the E-plane, at -3.9 mm for surveyed dentists and -3.3 mm for laypersons.[13] Finally, according to Lim, dentists evaluating Korean faces preferred the lower lip at -1.1 mm, and laypersons at -3.7 mm (-3.4 mm when combined), and this is well behind the Korean norm. When these results are compared with previous studies, results for Asian patients

showed similar values to those of Bowman and Johnston for Caucasian patients, indicating that Asian patients could be treated with similar protocols as Caucasian patients in terms of extraction or nonextraction.[14]

Ethnic differences in soft tissue composition and morphology can also influence upper lip response to incisor retraction, and many studies show significant differences between black and white subjects regarding adipose tissue distribution and amount, skin thickness and flexibility, and muscle density and weight.[15] In addition, cephalometric data show significant differences between normal hard and soft tissue values for black and white subjects, with blacks demonstrating greater incisor inclination and a more protrusive soft tissue profile.[16] On the contrary, it has been found that Japanese subjects have a significantly more retruded chin position, protruding mandibular incisors, and protruded lip positions compared with Caucasian norms, along with a significantly steeper mandibular plane.[17]

Even when treating Caucasian patients utilizing Caucasian norms, there is variability regarding this concept of "norm." McNamara and coworkers examined 136 Caucasian adults with ''ideal occlusions and well-balanced faces'' and found a combined average lower lip to *E*-plane for males and females of 3.58 mm [18] while Nanda and Ghosh examined 50 Caucasian adults with ''Class I occlusions and esthetically pleasing and balanced faces'' and reported an average protrusion of 3.13 mm.[19] Little agreement seems to remain with regard to Ricketts' norm of 2.0 mm for lower lip to *E*-plane, so perhaps to simplify, if all other characteristics of the patients are equal, the final determinant of an orthodontic treatment plan for borderline cases should be based on the finding that convex profiles are improved by extraction, but straight profiles are made

worse.[20]

Results of Previous Study: Borderline Class I Malocclusion in Black Patients

The results of a study completed by Johnson in 2013 (unpublished thesis, University of Maryland) evaluating the difference in the percentage of extraction and non-extraction cases when treatment planning borderline Class I malocclusions in black patients, proved to be consistent with the definition of a borderline case. A group of faculty in the University of Maryland Department of Orthodontics recommended extraction 57% of the time when evaluating borderline Class I malocclusions in black patients. The most common extraction pattern was that of all four first bicuspids, which was recommended approximately two-thirds of the time. Due to the bimaxillary dentoalveolar protrusion present in many black patients, it is not surprising that first bicuspids were extracted as frequently as they were.

The results of that study also identified the significant cephalometric and study model variables that influenced the decision to extract. The two significant variables were overbite (p = 0.017), followed by interarch midline discrepancy (p =0.019), which were both study model measurements. Cephalometrically, the WITS measurement approached significance, while IMPA, U1-SN and L1-NB were non-significant. While upper and lower crowding were both shown to differ significantly between the extraction and non-extraction groups, both variables proved to be non-significant in the evidence – based treatment decision.

It was worthy of note that dental overbite proved to be the most significant variable

in determining an evidence - based treatment plan of borderline Class I malocclusions in black patients, with less overbite resulting in a non-extraction approach. Those patients presenting with less overbite were more likely to be treated with a non-extraction approach than those with more overbite, and Johnson asserted that resting tongue position and soft tissue tonicity were significant cofactors in contributing to the decision not to extract.

Finally, the study determined by a stepwise forward logistic regression analysis that 100% predictability in treatment planning was obtained only when nine variables were included in the regression: overbite, interarch midline discrepancy, WITS, lower crowding, overjet, IMPA, U1-SN, L1-NB and upper crowding.[21]

III. PURPOSE OF THE PRESENT STUDY

The purpose of this study is to first determine if a group of faculty at the University of Maryland Department of Orthodontics finds there to be equal numbers of extraction and nonextraction cases when treatment planning borderline Class I malocclusions in Caucasian patients. Subsequently, this study will determine which variables are most important in the diagnosis and evidence-based treatment planning of these patients.

IV. HYPOTHESES

Null Hypotheses

$H_{0\,(1)}$: There is no significant difference in the percentage of extraction and non-extraction treatments planned when a group of experienced orthodontic faculty members evaluates borderline Class I malocclusions in Caucasian patients.

$H_{0(2)}$: There are no cephalometric or study model variables that are statistically better indicators of borderline Class I malocclusions in Caucasian patients.

Research Hypotheses

H_1: There is a significant difference in the percentage of extraction and non-extraction treatments planned when a group of experienced orthodontic faculty members evaluates borderline Class I malocclusions in Caucasian patients.

H_2: The cephalometric and study-model variables that are statistically better indicators of borderline Class I malocclusions in Caucasian patients are:

1. Upper Protrusion (U1-SN)
2. Upper Crowding
3. Lower Protrusion (L1-NB)
4. Lower Crowding

V. MATERIALS AND METHODS

Hypothesis 1 – Part I

Approval of the present protocol was obtained from the Institutional Review Board (IRB) of the University of Maryland Baltimore. A list of all Caucasian patients having completed initial orthodontic records within the last three years (2010-2012) at the University of Maryland Department of Orthodontics (*Initial Pre- Discriminant Sample)* was generated using a custom Crystal Report through Axium (Exan Academic, Las Vegas, NV). Specifically, the Report indicated the following: the patient's Axium chart number, the patient's first and last names, the date orthodontic records (CDT code D8660) were completed, and the faculty member assigned to the case. This list was saved electronically on a password protected MacBook Laptop. The initial report resulted in 180 subjects (Table 1).

Table 1. Study Subjects

	Initial Pre-Discriminant Sample	Pre-Discriminant Sample	Class I Pre-Discriminant Sample	Borderline Class I Malocclusions	Final Borderline Class I Malocclusions
Number of Participants	180	85	55	23	15

A preliminary review of the *Initial Pre-Discriminant Sample* was completed through inspection of the initial panoramic radiograph, stored in Dolphin Imaging (Patterson Dental Supply, Chatsworth, CA), for the presence of all permanent teeth,

excluding third molars. Complete initial orthodontic records, including past medical history, past dental history, results of clinical examination, PA cephalometric radiograph, lateral cephalometric radiograph, intraoral photographs, extraoral photographs and study models were also evaluated. Patients were excluded based on the following criteria: radiographic absence of any natural permanent tooth (except third molars) in either arch; presence of a dental prosthesis replacing a permanent tooth; presence of a supernumerary tooth, either radiographically or clinically; presence of any pathology (except caries determined not to affect the long-term prognosis of the tooth) and any previous orthodontic treatment (Appendix A). The sample that resulted was labeled *Pre-Discriminant Sample* and contained 85 subjects.

Next, the *Pre-Discriminant Sample* was further narrowed by including in the sample only those cases characterized by a Class I malocclusion and was thus identified as *Class I Pre-Discriminant Sample*. A Class I malocclusion was defined as the interdigitation of the maxillary first molar mesiobuccal cusp into the buccal groove of the mandibular first molar. Therefore, for this study, the following definition was used:

Class I: A millimeter range of anteroposterior (A/P) position of the maxillary first molar mesiobuccal cusp, from interdigitating in the buccal groove of the mandibular first molar (0.0 mm) to 1.0 mm anteroposterior to this position.

Patient study models were obtained from the University of Maryland Department of Orthodontics using the patient's Axium number. At this stage, only 55 subjects remained.

A custom cephalometric analysis, "Borderline Analysis Final," was created based on the measurements used in the previous study (see Appendix B) to identify borderline malocclusions within Dolphin Imaging. This analysis was run on lateral cephalograms

previously traced by the resident assigned to each case. Using the *Class I Pre-Discriminant Sample* list, the lateral cephalometric measurements from the "Borderline Analysis Final" were pasted into an Excel spreadsheet (Microsoft Excel for Mac 2011, Microsoft Corporation). The following information was included in the spreadsheet: Patient Axium number, Faculty Assigned, Resident Assigned, and Treatment Plan (Extraction/Non-extraction).

Next, the study models were evaluated for those measurements determined to be useful in the previous study (see Appendix C). These measurements were entered into the same Excel spreadsheet as the cephalometric measurements. Once all data was entered into the Excel spreadsheet, the patients were listed in alphabetical order and then given a sequential number. A separate Excel spreadsheet was created, which included all patient identifiers included in the initial spreadsheet with the assigned number. At this time, all patient identifiers were removed from the spreadsheet containing the measured data and only the assigned number remained to serve as identification. The protected spreadsheet was solely used for data evaluation from hereon.

As performed in the prior study, the cephalometric and study model variables and measurements for the *Class I Pre-Discriminant Sample* were then evaluated using Discriminant Function Analysis (SPSS Base 20.0 statistical package {SPSS, Inc; Chicago, IL}) to determine which subjects were considered to have borderline Class I malocclusions. Discriminant analysis uses a series of predictor values, both parametric and non – parametric, to predict a dichotomous dependent variable. In this case, the predictor variables were cephalometric and study model variables, and the dependent variable was extraction or non – extraction treatment. The discriminant function was

used to generate predictor summarizing discriminant scores for each of the subjects. Group probability is defined as the probability of belonging solely to the extraction group or solely to the non-extraction group, with the highest number (1.0) implying membership in one group only. The purpose of this discriminant analysis was to determine borderline cases or "grey area," similar to the way Paquette did in his 1992 Class II study, and this could therefore be accomplished by finding cases with lower group probablilty values. Discriminant analysis deals simultaneously with large numbers of predicitve variables, and the main reason that this analysis was employed was its ability to predict group membership, to identify patients who could belong to either group (borderline), and finally to establish treatment predictors. Each subject was assigned either a 0, for initial non- extraction treatment plan, or a 1, for initial extraction treatment plan, and in this case, a group probability (P) value less than 0.99 indicated a patient whose malocclusion was considered borderline with respect to the treatment decision of extraction or non – extraction.

The resulting sample of 23 subjects was identified as *Borderline Class I Malocclusions*. The sample consisted of 18 borderline non-extraction cases and 5 borderline extraction cases with P values below 0.99. Since 23 cases was too large of a sample for faculty to reasonably evaluate, the 10 non-extraction subjects with the lowest P values and all 5 extraction subjects were chosen to represent the most borderline of the cases. The resulting sample of 15 subjects was identified as *Final Borderline Class I Malocclusions* (Figure 1).

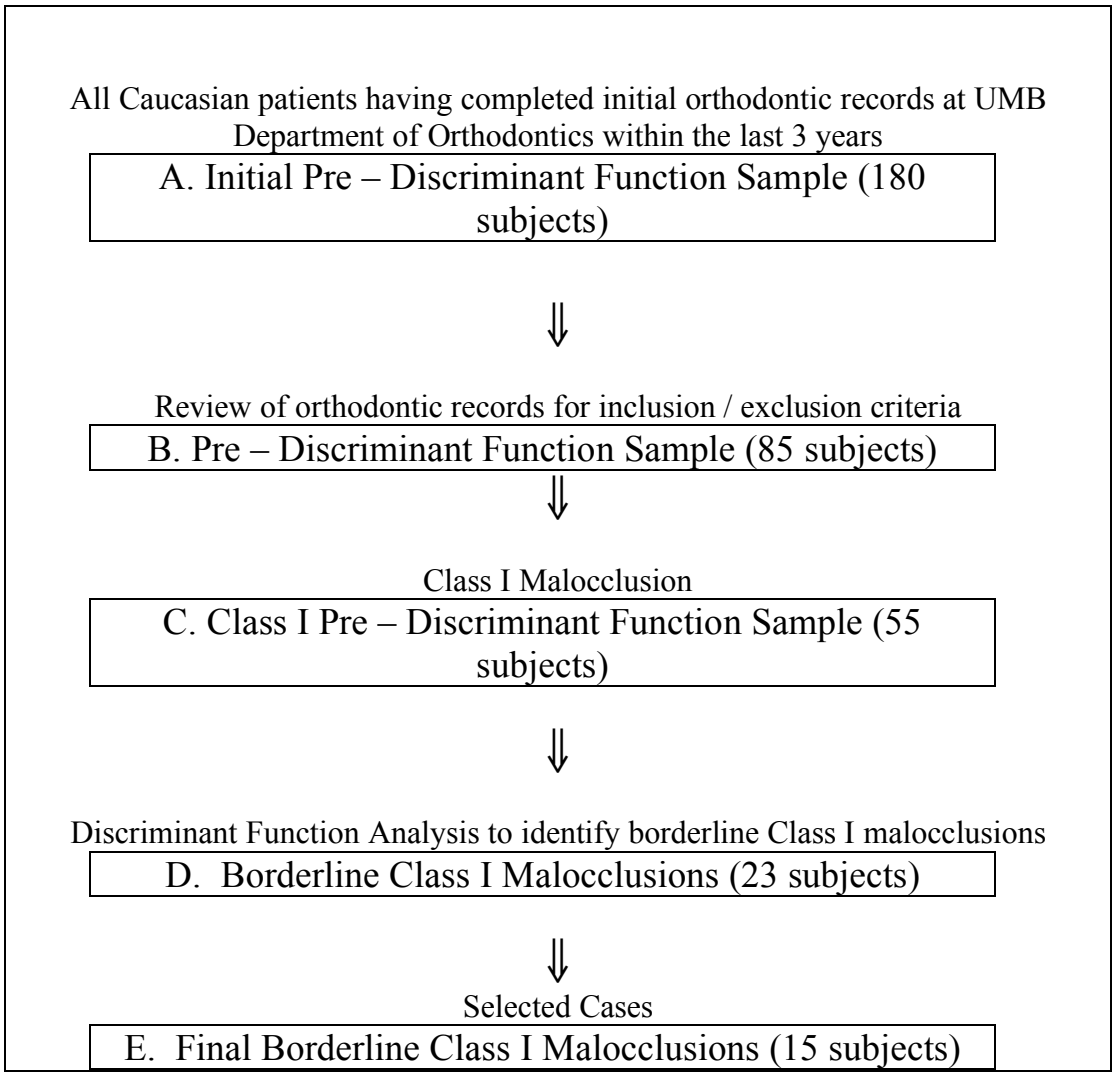

Figure 1. Schematic of Methods and Resulting Sample Size

Hypothesis 1 – Part 2

A paper patient chart was then created for each of these 15 patients, which included the complete set of orthodontic records except for the study models. All patient identifiers were eliminated from the patient charts. Black banners were placed on all full facial photographs to cover the eyes of each patient. The charts were then labeled sequentially, from 1-15, and these numbers were documented in the Excel spreadsheet to indicate

which chart corresponded to which patient.

All orthodontic faculty members in the Department of Orthodontics at the University of Maryland were asked to participate in this study. Eleven faculty members, including two black faculty members and one solely Damon practitioner, participated in this phase of the study. Complete orthodontic records, including the paper patient chart and study models, were provided to those faculty members who agreed to participate. The 11 faculty members were asked to develop basic treatment plans for each of the 15 cases, indicating only if he/she would extract, and if so, which teeth he/she would extract. Each was asked to provide his/her answer on a form, which indicated the protected chart number, faculty name, and treatment plan (see Figure 2). The percentage of extraction vs. non-extraction decisions for each case and for each individual faculty member was then determined.

A Chi-square Goodness of Fit Test was used to compare faculty recommendation percentages with their expected percentages for significant differences. A p value of 0.05 was considered significant.

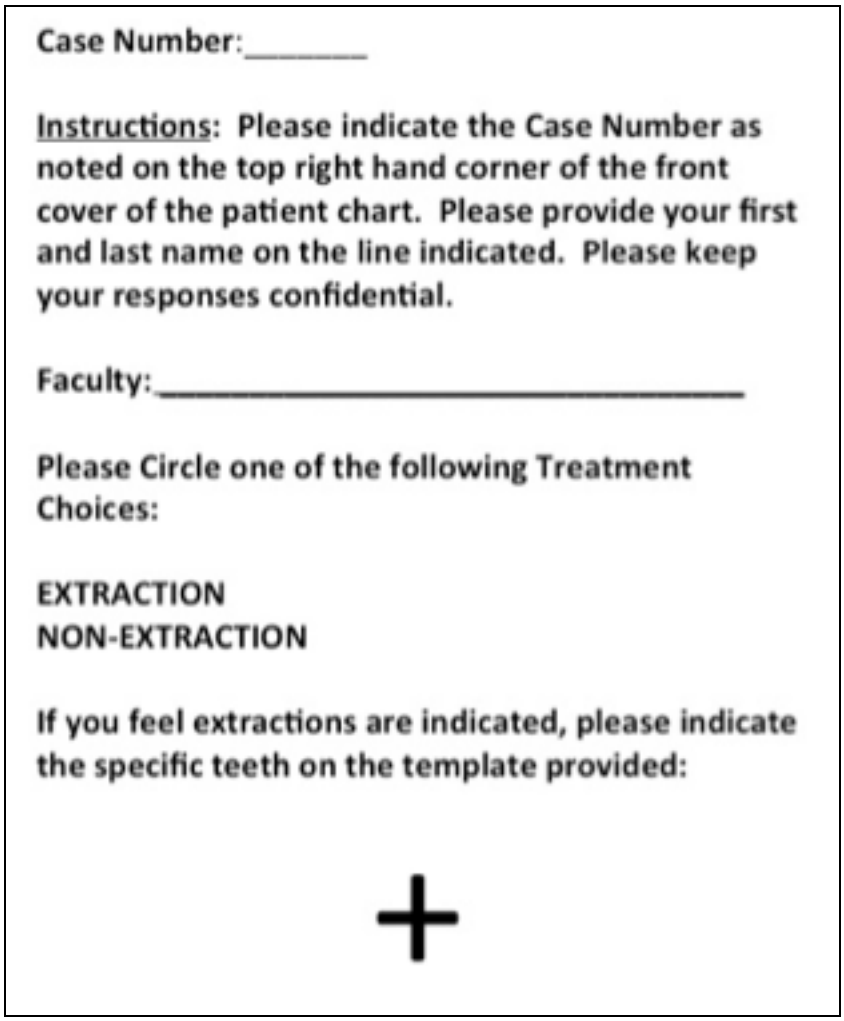

Figure 2. Treatment Plan Form

Hypothesis 2

A Stepwise Forward Logistic Regression Analysis (SPSS Base 20.0 (SPSS, Inc; Chicago, IL)) was used to determine those cephalometric and study model variables that served as the best indicators of borderline Class I malocclusions in Caucasian patients.

VI. RESULTS

Part I – Evaluation of Hypothesis 1: Results of Discriminant Function Analysis

The use of discriminant analysis ensured that only borderline cases were evaluated by the faculty members (Table 2). The 15 cases with the lowest group probability (P) values were chosen for analysis (see Table 2). Also shown in this table is the actual treatment performed in each case.

Table 2. Results of Discriminant Analysis

New Protected Case Number	Actual Treatment Plan	Discriminant Value *	Group Probability Value (P)
3	NE	0	0.747
10	NE	0	0.915
15	NE	0	0.934
8	NE	0	0.966
12	NE	0	0.978
6	NE	0	0.981
1	NE	0	0.989
4	NE	0	0.990
13	NE	0	0.991
9	NE	0	0.993
5	E	1	0.990
2	E	1	0.996
14	E	1	0.998
11	E	1	0.999
7	E	1	0.999

* Discriminant Value 0 = treated non-extraction, 1 = treated with extraction

Part I – Evaluation of Hypothesis 1: Results of Faculty Evaluations

The results of the first stage of this study, which evaluated the percentage of

extraction and non-extraction treatments recommended by faculty members, found that there was no significant difference in the percentage of extraction and non- extraction treatments planned. Eleven faculty members evaluated 15 cases each, for a total of 165 analyses. There was no significant difference between the treatment plan recommended and the 50/50 treatment expected for borderline cases (X^2=0.055, p = 0.8153), although extraction treatment was slightly more likely to be chosen by those surveyed (50.9%) than non-extraction treatment (49.1%) (Table 3).

Table 3. Extraction vs. Non-Extraction: X^2 Goodness of Fit Test
(X^2=0.055, p = 0.8153)

	Observed	Expected Value (No Differences Predicited)
Non - Extraction	81 (49.1%)	82.5 (50%)
Extraction	84 (50.9%)	82.5 (50%)

Extraction Patterns

Within the extraction treatment plans, 44.1% of the extraction plans involved four first bicuspids, 14.3% involved first and second bicuspids, 16.7% involved four second bicuspids and 9.5% involved only one lower incisor. Lastly, 7.1% involved only 2 bicuspids, and 8.3% involved an asymmetric pattern of four bicuspid extractions (Table 4).

Table 4. Extraction Patterns

Pattern	Percent
4 First Bicuspids	44.1
2 First Bicuspids / 2 Second Bicuspids	14.3
4 Second Bicuspids	16.7
1 Lower Incisor	9.5
2 Bicuspids	7.1
4 Bicuspids, Assymetric	8.3

Faculty Extraction Recommendations

Three cases (cases 1, 15, and 8) were found to have unanimous non-extraction decisions, and three (cases 5, 2, and 14) were found to have unanimous extraction decisions (Table 5).

Table 5. Final Faculty Percent Extraction

Protected Case Number	Initial Treatment Plan	Final Faculty Percent Extraction
1	NE	0%
15	NE	0%
8	NE	0%
12	NE	18%
9	NE	18%
13	NE	36%
10	NE	45%
3	NE	55%
6	NE	64%
11	E	64%
4	NE	73%
7	E	91%
5	E	100%
2	E	100%
14	E	100%

Faculty Extraction Frequency

The mean faculty extraction rate was 50.9% +/- 11.3% with a median extraction rate of 46.7%. One of the faculty members (3) recommended extractions less frequently, as determined by falling one standard deviation below the average for the group, while two of the faculty members (7 and 10) recommended extractions more frequently as their recommendations exceeded the average for the group by one standard deviation (Table 6).

Table 6. Faculty Extraction Frequency

Faculty	Extraction Frequency
3	33.3**
1	40
2	40
5	46.7
8^	46.7
11	46.7
6	53.3
4	60
9	60
7^^	66.7***
10^^	66.7***
Mean	50.9
Median	46.7
Standard Deviation	11.3

^ Damon Practitioner
^^Black Faculty Members
**1 SD below the mean
***1 SD above the mean

Part II – Evaluation of Hypothesis 2

The results of the second stage of the study identified cephalometric and study model variables that were indicators of borderline Class I malocclusions in Caucasian patients. The variables proved to be different than those hypothesized (upper protrusion, lower protrusion, upper crowding, and lower crowding), with the exception of upper crowding, which was both predicted and found to be significant.

The four variables with the highest B value significance levels were identified through logistic regression at the fourth step to be the mandibular intercanine width and maxillary arch crowding (both study model variables), followed by the cephalometric Z-angle and the upper lip to E-plane measurement (Table 7, Step 4). The stepwise forward logistic regression analysis yielded B value significance levels, and the higher the value, the more important the variable was towards predicting borderline treatment. Mandibular intercanine width and maxillary arch length discrepancy yielded the highest predictive B value significance levels, with Z-angle and upper lip to E-plane yielding lower values, but the inclusion of all four variables produced the highest predictability possible. By the fourth step, the high predictive value of all four variables was shown by significance levels of 0.997 and 0.998.

The stepwise forward logistic regression analysis adds variables one at a time until the best prediction is gained, and in this case, four steps were needed to complete the regression. The first step resulted in mandibular intercanine width, which had only very little predictive value. The second step added maxillary arch discrepancy, and the third

included the Z angle. By the fourth step, the highest predictive value was achieved.

Table 7. Results of Stepwise Forward Logistic Regression

	B	S.E.	df	Sig. of B	Exp(B)
Step 1: **Mand. Canine**	.64	.36	1	.075	.529
Step 2: **Mand. Canine**	1.57	.83	1	.058	.209
Max. Arch Discrepancy	.70	.43	1	.103	.497
Step 3: **Z Angle**	6.92	1194.28	1	.995	.001
Mand. Canine	31.50	5193.07	1	.995	.000
Max. Arch Discrepancy	28.41	4858.52	1	.995	.000
Step 4: **Z Angle**	4.98	1285.82	1	**.997**	.007
U Lip to E Plane	5.31	2448.50	1	**.998**	.005
Mand. Canine	19.21	4771.01	1	**.997**	.000
Max. ArchDiscrepancy	17.74	4385.39	1	**.997**	.000

VII. DISCUSSION

The four most significant indicators of borderline Class I malocclusions for Caucasian patients in this study were determined to be the mandibular intercanine width, the amount of maxillary arch crowding, the Z-angle, and the upper lip to E-plane measurement. However, due to the limited number of cases proving to be borderline, the results and conclusions of this study should be referred to cautiously.

The concept that the mandibular intercanine dimension is a stable and inviolable measurement has been repeatedly supported in the literature.[22] When treating a borderline case with even moderate crowding, increasing the intercanine width as a means to address anterior crowding should be avoided. So it is not surprising that this study found the intercanine width to be a significant indicator of borderline malocclusion. Current literature supports the notion that the mandibular intercanine width tends to expand during treatment by 0.8 to 2.0 mm, regardless of pretreatment occlusal classification or whether treatment was extraction or nonextraction. Furthermore, the mandibular intercanine width tends to constrict postretention by 1.2 to 1.9 mm, regardless of pretreatment classification or whether treatment was extraction or nonextraction. Since the net change in mandibular intercanine width is then found to be approximately zero, the literature currently supports the concept of maintenance of original intercanine width in orthodontic treatment.[23]

This study also found that a significant indicator of borderline malocclusion is the maxillary arch discrepancy (crowding), and it is not surprising that the difference between the space required and the amount of space available for the alignment of the

upper teeth, plays such an important role in the decision to extract or not in orthodontics. Interestingly however, the orientation of the lower incisor to the basal bone or the face as appraised in various angles like IMPA or FMIA was not found to be significant in this study. In similar studies, the lower incisor angle was found to be an important variable allowing the clinician to discriminate between the two treatment modalities.[24 25 26 27] Historically, the lower arch has been the foundation of treatment planning, with lower incisor position being the primary focus. However, there has recently been a paradigm shift to focusing more on the position of the upper incisors to maximize facial esthetics, and if compromise is to occur, sacrificing lower incisor position to accommodate facial esthetics.

This concept was further supported by the finding that both the cephalometeric Z-angle and upper lip to E-plane measurements were significant indicators of borderline malocclusion. Merrifield created the Z-angle (the angle between Frankfort plane to a line from pogonion to upper lip vermillion), to identify whether facial balance was incorrect due to a soft tissue disharmony, hard tissue disharmony, or combination of both. Merrifield determined the ideal Z angle range was 70-80° with the ideal being 75- 78° depending on age and gender, and if lip position is considered protrusive, extraction of the premolars followed by retraction of the anterior segment can help improve the profile.[28]

Furthermore, Ricketts felt that for the average Caucasian face to have a pleasing facial profile, the lower lip should be 2mm behind the E-plane, and the upper lip 4mm behind the line, with variations for patients of different ethnic backgrounds. When the lips show inadequate projection, the orthodontist may then be reluctant to extract, but

when they exceed the E-plane, the choice to extract may become more clear. The finding that both of these cephalometric profile-based variables proved to be significant in the decision to recommend extractions only verifies the important role facial esthetics plays for orthodontists today when treating most specifically borderline malocclusions.[29 30 31]

Furthermore, the fact that the extraction of four first bicuspids was the most commonly recommended extraction pattern only further supports the idea that soft tissue profile and facial esthetics play an important role in treatment planning of these borderline patients.

Lastly, it is interesting to note that contrary to previous studies that found that black laypersons and orthodontists found fuller profiles to more esthetically acceptable, the two black orthodontists in this study recommended significantly more extraction treatments than their counterparts. It is also interesting to note that the sole Damon practitioner's extraction frequency was similar to that of practitioners utilizing traditional edgewise therapy (Table 6).

VIII. CONCLUSIONS

The result that there was no significant difference in the percentage of extraction and non-extraction treatments recommended when faculty treatment planned borderline Class I malocclusions in Caucasian patients proved to be consistent with the definition of a borderline case. Due to the limited size of the study sample, no definitive conclusions can be made regarding the importance of the individual variables in determining an evidence - based treatment plan. Several inferences may be made however, and the conclusions of this study were as follows:

1. The results of the first stage of this study, which evaluated the percentage of extraction and non-extraction recommendations made by faculty members when evaluating borderline Class I malocclusions in Caucasian patients, found that there was no significant difference in the percentage of extraction and non- extraction treatments planned. Faculty at the University of Maryland Department of Orthodontics recommended extractions 50.9% of the time when evaluating borderline Class I malocclusions in Caucasian patients.
2. The most common extraction pattern was the extraction of all four first bicuspids (44.1%).
3. The results of the second stage of the study identified cephalometric and study model indicators of borderline Class I malocclusions in Caucasian patients. The variables proved to be different than those hypothesized (upper protrusion, lower protrusion, upper crowding, and lower crowding), with the exception of upper crowding, which did prove

to be significant. The four most significant variables, as determined through logistic regression, were the mandibular intercanine width measurement and maxillary arch crowding (both study model variables), followed by the cephalometric Z-angle and the upper lip to E-plane measurement.

IX. APPENDICES

Appendix A – Inclusion/Exclusion Criteria

Inclusion Criteria

Orthodontic treatment started at the University of Maryland Department of Orthodontics
Clinical or Radiographic presence of all permanent teeth (except third molars)
Complete Initial Orthodontic Records consisting of:
- Past Medical History
- Past Dental History
- Clinical Examination
- Panoramic Radiograph
- PA Cephalometric Radiograph
- Lateral Cephalometric Radiograph
- Intraoral Photographs:
  - Frontal Intraoral
  - Maxillary Occlusal
  - Mandibular Occlusal
  - Right Buccal
  - Left Buccal

Extraoral Photographs:
- Frontal Repose
- Frontal Smiling
- Profile Repose

Study Models

Exclusion Criteria

Radiographic absence of any natural permanent tooth (except third molars) in either maxillary or mandibular arch
Presence of a dental prosthesis replacing a permanent tooth
Presence of a supernumerary tooth, either radiographically or clinically
Presence of any pathology (except caries determined not to affect long-term prognosis of tooth)
Any previous orthodontic treatment

Appendix B – Cephalometric Variables Utilized for Borderline Analysis

Linear
Overjet
Overbite
Wits
Upper E Plane
Lower E Plane
U6-PTV
U1-NA
L1-NB
L1-APog
Ar-Gn
Pog-NB
N-ANS
ANS-Me
N-Me
S-Ar
S-Go

Angular
SNA
SNB
ANB
Y Axis
PP-OP (**PP-SN** – this measurement will be subtracted from OP-SN to obtain PP-SN)
OP-SN
Interincisal Angle
U1-SN
U1-NA
L1-NB
Z Angle
FMA
FMIA
IMPA

Appendix C – Study Model Analysis

Individual Tooth Size
Upper Canine Arch Width – Cusp tip to Cusp tip
Lower Canine Arch Width – Cusp tip to Cusp tip
Upper Second Premolar Arch Width – Lingual margin at long axis to Lingual margin at long axis
Lower Second Premolar Arch Width – Lingual margin at long axis to Lingual margin at long axis
Upper Molar Arch Width – Lingual margin at long axis to Lingual margin at long axis
Lower Molar Arch Width – Lingual margin at long axis to Lingual margin at long axis
Upper Arch Length (Mesial 6 - Contact of 1's - Mesial 6)
Lower Arch Length (Mesial 6 - Contact of 1's - Mesial 6)
Upper Arch Length (Mesial 6 - Mesial 3 - Contact of 1's – Mesial 3 – Mesial 6)
Lower Arch Length (Mesial 6 - Mesial 3 - Contact of 1's – Mesial 3 – Mesial 6)
Upper Arch Circumference (Measured with a copper wire from Mesial of 6 to Mesial of 6)
Lower Arch Circumference (Measured with a copper wire from Mesial of 6 to Mesial of 6)
Upper Discrepancy Length (Based on the four-segment measure of arch length)
Lower Discrepancy Length (Based on the four-segment measure of arch length)
Upper Discrepancy Circumference (Based on the Arch Circumference)
Lower Discrepancy Circumference (Based on the Arch Circumference)
Lower Anterior Irregularity
Upper Arch Symmetry (separate measures of right and left dental arch width measured at the molars taken at the midline)
Lower Arch Symmetry (separate measures of right and left dental arch width measured at the molars taken at the midline)
Overjet – measured from the facial of the most anterior lower incisor to the facial of the most anterior upper incisor)
Overbite
Interarch Midline Discrepancy – the horiztonal distance, parallel to the occlusal plane, between the most incisal midline points of the upper and lower central incisors
Curve of Spee – measured as the greatest depth along the curve.

X. REFERENCES

[1] AAO, Clinical Practice Guidelines, aaoinfo.org

[2] Burrow, S. Jack, The Impact of Extractions on Facial and Smile Aesthetics. Seminars in Orthodontics, Vol 18, No 3 (September), 2012: pp 202-209

[3] Burrow, S. Jack, The Impact of Extractions on Facial and Smile Aesthetics. Seminars in Orthodontics, Vol 18, No 3 (September), 2012: pp 202-209

[4] Johnson, Evan M. An In Depth Analysis of Borderline Class I Malocclusions in Black Patients at the University of Maryland, unpublished thesis, 2013.

[5] AAO, Clinical Practice Guidelines, aooinfo.org

[6] Steiner CC, Cephalometrics in clinical practice. Angle Orthod 1959;29:8-29.

[7] Steiner CC. The use of cephalometrics as an aid to planning and assessing orthodontic treatment. Am J Orthod 1960;46:721-35.

[8] Steiner CC, Cephalometrics for you and me. Am J Orthod 1953;39:729-55.

[9] McNamara, James A. Cephalometric Analysis of Untreated Adults with Ideal Facial and Occlusal Relationships. The Interanational Journal of Adult Orthodontics and Orthognathic Surgery, Vol 3, 2008.

[10] Arnett GW, Bergman RT. Facial keys to orthodontic diagnosis and treatment planning. Part I. Am J Orthod Dentofac Orthop 1993; 103: 299-312.

[11] Germeç and Taner. Effects of extraction and nonextraction therapy with air-rotor stripping on facial esthetics in postadolescent borderline patients. Am J Orthod Dentofacial Orthop 2008;133:539-49.

[12] Scott SH, Johnston LE. The perceived impact of extraction and nonextraction treatments on matched samples of African American patients. Am J Orthod Dentofacial

Orthop 1999; 116: 352-358.

[13] Bowman SJ, Johnston LE Jr. The esthetic impact of extraction and nonextraction treatments on Caucasian patients. Angle Orthod. 2000 Feb;70(1):3-10.

[14] Lim, Ko, and Hwang, Esthetic impact of premolar extraction and nonextraction treatments on Korean borderline patients. American Journal of Orthodontics and Dentofacial Orthopedics Volume 133, Number 4, 2008.

[15] Brock et al. Ethnic differences in upper lip response to incisor retraction. Am J Orthod Dentofacial Orthop 2005;127:683-91.

[16] Brock et al. Ethnic differences in upper lip response to incisor retraction. Am J Orthod Dentofacial Orthop 2005;127:683-91.

[17] L Kavitha and K Karthik, Comparison of cephalometric norms of caucasians and non-caucasians: A forensic aid in ethnic determination. J Forensic Dent Sci. 2012 Jan-Jun; 4(1): 53–55.

[18] McNamara, James A. Cephalometric Analysis of Untreated Adults with Ideal Facial and Occlusal Relationships. The Interanational Journal of Adult Orthodontics and Orthognathic Surgery, Vol 3, 2008.

[19] Nanda RS, Ghosh J. Facial soft tissue harmony and growth in orthodontic treatment. Semin Orthod. 1995 Jun;1(2):67-81.

[20] Scott SH, Johnston LE. The perceived impact of extraction and nonextraction treatments on matched samples of African American patients. Am J Orthod Dentofacial Orthop 1999; 116: 352-358.

[21] Johnson, Evan M. An In Depth Analysis of Borderline Class I Malocclusions in Black Patients at the University of Maryland, unpublished thesis, 2013.

[22] Burke, S P & Silveira, A M & Goldsmith, L J & Yancey, J M & Van Stewart, A & Scarfe, W C. (1998). A meta-analysis of mandibular intercanine width in treatment and postretention. The Angle orthodontist, 68

[23] Burke, S P & Silveira, A M & Goldsmith, L J & Yancey, J M & Van Stewart, A & Scarfe, W C. (1998). A meta-analysis of mandibular intercanine width in treatment and postretention. The Angle orthodontist, 68.)

[24] Paquette DE, Beattie JR, Johnston LE Jr. A long-term comparison of nonextraction and premolar extraction edgewise therapy in "borderline" Class II patients. Am J Orthod Dentofacial Orthop. 1992; 102:1–14.

[25] Luppanapornlarp S, Johnston LE Jr. The effects of premolar-extraction: a long-term comparison of outcomes in "clear-cut" extraction and nonextraction Class II patients. Angle Orthod. 1993; 63:257–72.

[26] Beattie JR, Paquette DE, Johnston LE Jr. The functional impact of extraction and nonextraction treatments: a long-term comparison in patients with "borderline", equally susceptible Class II malocclusions. Am J Orthod Dentofacial Orthop. 1994; 105:444–9.

[27] Konstantonis D. The impact of extraction vs nonextraction treatment on soft tissue changes in Class I borderline malocclusions. Angle Orthod. 2012; 82:209–17.

[28] Erdinc, Nanda, and Dandajena. Profile changes of patients treated with and without premolar extractions, Am J Orthod Dentofacial Orthop 2007;132:324-31)

[29] Merrifield LL. The profile line as an aid in critically evaluating facial esthetics. Am J Orthod 1966;52:804-22.

[30] Ricketts RM. Planning treatment on the basis of the facial pattern and an estimate of its growth. Angle Orthod 1957;27:14-37.

[31] Boley JC, Pontier JP, Smith S, Fulbright M. Facial changes in extraction and nonextraction patients. Angle Orthod. 1998; 68:539–46.