THE CONSISTENCY OF ORTHODONTIC DIAGNOSIS AND TREATMENT PLANNING

Nicholas P. Azar, D.M.D

An Abstract Presented to the Graduate Faculty of Saint Louis University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Dentistry (Research) 2012
Abstract

**Introduction:** The cephalometric radiograph has been a staple in orthodontic diagnosis and treatment planning since its introduction by Broadbent in 1931. Many analyses have been created by which to compare skeletal and dental relationships. Little research has been performed evaluating how valuable a cephalometric radiograph is in diagnosing and treatment planning orthodontic patients with consistency. **Purpose:** The aim of this study was to focus on the value that orthodontists place on cephalometric radiographs when diagnosing and treatment planning on two separate occasions.

**Materials and Methods:** Ten faculty members from SLU CADE were chosen at random to evaluate 65 sets of orthodontic records excluding the cephalometric radiograph. Each participant evaluated 11 of the 65 total records, of which 6 had been treated by that doctor, and the remaining 5 by none of the participants. A questionnaire of various skeletal questions and treatment plan options was applied to each case. The responses to each case treated by the participants (named “internal data”) were analyzed separate from the 5 universal cases (named “external data”) providing two sets of data. Skeletal relationships were calculated for external data only in order to compare evenly between the participants. Consistency of questionnaire responses was based on Kappa agreement measures and rates >0.60 were deemed statistically significant. **Results:** All internal data with regards to planning the use of auxiliary appliances, the decision to extract, and if surgical treatment was indicated came back at least substantially consistent to the original treatment plans. Estimating the patients’ skeletal classification, planning the use of an auxiliary appliance, and whether surgical treatment was indicated were consistently significant for the external data. **Conclusions:** Based on these findings it can be
concluded that orthodontists are confident in diagnosing and treatment planning without the use of a cephalometric radiograph and are consistent in their treatment plan decisions for cases they have treated in the past. However, there is little consistency of treatment plan decisions between doctors for cases treated by an unknown orthodontist. Finally, skeletal-dental relationships cannot be determined without access to a cephalometric radiograph.
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A Thesis Presented to the Graduate Faculty of Saint Louis University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Dentistry (Research) 2012
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Chairperson and Advisor

Professor Rolf G. Behrents

Assistant Professor Donald Oliver

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Dedication

This thesis is dedicated to my family and parents who have supported and guided me through all my years of education. To my beautiful wife, Jill, you have been with me every step of the way and without your endless patience, love, and support none of this would be possible. To my kids, Joseph, Adelaide, and Jane, because even on the worst of days coming home to see your smiling faces gives me the desire to keep working hard. Finally, to my parents, you have provided me with all the necessary tools to be successful in life and your willingness to put your kids’ needs first will never be forgotten.
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CHAPTER 1: INTRODUCTION

Prior to initiating treatment orthodontists perform a comprehensive examination consisting of medical and dental history and an intraoral examination. Diagnostic records are then collected which normally includes photographs, study models and panoramic and cephalometric radiographs. The records provide clinicians with the necessary facial, dental and skeletal information needed to thoroughly diagnosis and treatment plan orthodontic treatment. While photographs and study models offer no harm to the patient, standard orthodontic radiographs expose patients to various levels of radiation. Although radiation levels experienced by dental radiographs are low\textsuperscript{1,2} when compared to medical radiation scans and everyday background exposures,\textsuperscript{3} there must be clinical justification for exposing patients to x-rays. The American Dental Association believes “dentists should weigh the benefits of dental radiographs against the consequences of increasing a patient’s exposure to radiation” and practice the “as low as reasonably achievable” (ALARA) principle to minimize exposure to radiation.\textsuperscript{4} The primary purpose of the radiographic examination is to provide additional information that may not be evident clinically.\textsuperscript{5} However, many orthodontic textbooks do not describe a radiograph protocol. Rather, they explain diagnosis and treatment plan benefits for periapical, bitewing, panoramic and cephalometric radiographs.\textsuperscript{6-9}

Bitewing, periapical and panoramic radiographs enable identification of carious lesions, periapical and bony pathology, potential TMJ dysfunction and dental development. Specific to orthodontics the lateral cephalometric radiograph provides information about skeletal size, position, proportion and symmetry of the individual through which it is possible to assess skeletal disharmonies. In 1986 Atchinson reported
a 90% response rate by orthodontists who routinely take lateral cephalometric and panoramic radiographs at the initial exam. However, there is little research demonstrating the value that orthodontists place on these radiographs for diagnosis and treatment planning purposes. Given the high percentage of radiographs taken at initial exams demonstrated by Atchinson and the little research to prove otherwise, is it fair to assume this number could be lowered thereby diminishing the amounts of radiation exposure to our patients? Most orthodontists would agree cephalometric radiographs provide skeletal and dental relationships otherwise unattainable. However, is this amount of information produced a necessity in all orthodontic cases? The aim of this study is to focus on the value that orthodontists place on cephalometric radiographs when diagnosing and treatment planning orthodontic treatment. The diagnosis of facial, dental and skeletal relationships and their contributions to orthodontic treatment planning will be addressed in the literature review.
Chapter 2: Review of the Literature

Diagnosis

Orthodontic treatment is generally performed to improve a person’s life by increasing harmony between dental and jaw relationships. Prior to treatment records are taken in order to diagnose and treatment plan the case. According to Graber the purpose of diagnosis is twofold: document the patient’s initial condition and supplement the diagnostic information with a clinical examination. Standard records consist of: dental casts, intra and extra-oral photographs, panoramic and cephalometric radiographs and direct clinical measurements.

The clinical examination is the first time the doctor has the opportunity to assess the malocclusion and begin formulating a treatment plan. Graber points out three essential outcomes of the clinical exam: overall impression of the oral health and soft tissues, jaw function, and dental-facial esthetics. Periodontal disease, temporomandibular joint dysfunction, decay, and prosthodontic concerns are noted and must be considered in the diagnosis and treatment plan.

Orthodontic diagnosis and treatment planning has three components: facial, dental and skeletal diagnoses. The facial diagnosis is performed immediately upon meeting the patient and has become increasingly important as the orthodontic specialty is undergoing a paradigm shift from hard tissue analysis as the primary concern to soft tissue analysis. As depicted in Table 1.1, Angle’s paradigm of ideal occlusion and harmony of the dental and skeletal components is being replaced by the soft tissue esthetics and functional goals of the soft tissue paradigm. Angle believed diagnosis and treatment planning should
focus on skeletal and dental components and the soft tissue relationships were a byproduct. According to the soft tissue paradigm, proportions of the soft tissue integument of the face and the relationship of the dentition to the lips and face are the major determinants of facial appearance. Therefore, ideal soft tissue relationships and esthetics are considered first and the skeletal and dental relationships are secondary goals.6,8

Table 2.1 Angle paradigm vs. soft tissue paradigm: A new way of looking at treatment goals (adapted from Proffit et al.)6

<table>
<thead>
<tr>
<th></th>
<th>Angle Paradigm</th>
<th>Soft Tissue Paradigm</th>
</tr>
</thead>
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<tr>
<td>Primary Goal of Treatment</td>
<td>Ideal dental occlusion</td>
<td>Ideal soft tissue proportions and adaptations</td>
</tr>
<tr>
<td>Secondary Goal of Treatment</td>
<td>Jaw relationships</td>
<td>Functional occlusion</td>
</tr>
<tr>
<td>Hard versus Soft Tissue Relationships</td>
<td>Ideal skeletal and dental relationships produces ideal soft tissue</td>
<td>Ideal soft tissue defines ideal skeletal and dental relationships</td>
</tr>
<tr>
<td>Diagnostic Emphasis</td>
<td>Dental casts and cephalometric radiographs</td>
<td>Clinical examination of soft tissues</td>
</tr>
<tr>
<td>Treatment Approach</td>
<td>Obtain ideal dental and skeletal relationships and the soft tissues will be okay</td>
<td>Determine ideal soft tissue relationships and then place the jaws and teeth as needed to obtain them</td>
</tr>
</tbody>
</table>
Facial Evaluation and Diagnosis

During the initial clinical exam facial photos are taken and most commonly include facial frontal, facial profile, facial smile, and oblique smile (Figure 2.1).²

Figure 2.1: Four standard orthodontic facial photos

Lay people are increasingly aware of facial esthetics, dental irregularities and malocclusions. Otuyemi et al. demonstrated a strong relationship in the perceptions of dental appearance by patients and parents.¹¹ Moreover, patients have opinions on their treatment outcomes. Ethically, orthodontists have a responsibility to consider patients’ goals in treatment. The concept of paternalism versus patient autonomy is not defensible ethically, legally or practically.¹²,¹³ Facial photos enable two-dimensional soft tissue analysis in horizontal and vertical planes for the purposes of evaluating facial asymmetries and soft tissue characteristics. In addition, lip fullness, lip incompetence, chin protrusion, facial convexity, gingival display, smile arc and overall facial balance should be considered in the overall treatment plan. Facial photos are examined with the patient and soft tissue goals are agreed upon.
Analysis of the frontal facial photo focuses on proportions and asymmetries. A small degree of bilateral facial asymmetry exists in essentially all normal individuals, and this has been termed “normal asymmetry.” An ideally proportioned face can be divided into central, medial, and lateral equal fifths, and superior, middle, and inferior facial thirds. The study of facial balance using photographs is not unique to orthodontists. Figure 2.2 demonstrates the dimensions the anthropologist, Farkas, studied on Canadians and modern Europeans providing the data shown in Table 2.2. Modern day orthodontists routinely analyze facial photos for symmetry in facial fifths and facial thirds to determine soft tissue balance. Farkas’ work provided norms for twelve facial dimensions routinely used in orthodontic diagnosis.

Figure 2.2: Anthropometric facial analysis (adapted from Farkas)
Table 2.2: Soft tissue averages determined by Farkas\textsuperscript{14}

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Graduating students</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Zygomatic width (Zy-Zy) (mm)</td>
<td>137 (4.3)</td>
<td>130 (5.3)</td>
</tr>
<tr>
<td>2. Gonial Width (Go-Go) (mm)</td>
<td>97 (5.8)</td>
<td>91 (5.9)</td>
</tr>
<tr>
<td>3. Intercanthal distance (mm)</td>
<td>33 (2.7)</td>
<td>32 (2.4)</td>
</tr>
<tr>
<td>4. Pupil-midfacial distance (mm)</td>
<td>33 (2.0)</td>
<td>31 (1.8)</td>
</tr>
<tr>
<td>5. Nasal base width (mm)</td>
<td>35 (2.6)</td>
<td>31 (1.9)</td>
</tr>
<tr>
<td>6. Mouth width (mm)</td>
<td>53 (3.3)</td>
<td>50 (3.2)</td>
</tr>
<tr>
<td>7. Face Height (N-Gn) (mm)</td>
<td>121 (0.8)</td>
<td>112 (5.2)</td>
</tr>
<tr>
<td>8. Lower face height (subnasale-Gn)(mm)</td>
<td>72 (6.0)</td>
<td>66 (4.5)</td>
</tr>
<tr>
<td>9. Upper lip vermillion (mm)</td>
<td>8.9 (1.5)</td>
<td>8.4 (1.3)</td>
</tr>
<tr>
<td>10. Lower lip vermillion (mm)</td>
<td>10.4 (1.9)</td>
<td>9.7 (1.6)</td>
</tr>
<tr>
<td>11. Nasolabial angle (degrees)</td>
<td>99 (8.0)</td>
<td>99 (8.7)</td>
</tr>
<tr>
<td>12. Nasofrontal angle (degrees)</td>
<td>131 (8.1)</td>
<td>134 (1.8)</td>
</tr>
</tbody>
</table>

Analyzing the frontal view in terms of fifths and thirds points to the potential asymmetries and helps the clinician determine if treatment should address the discrepancy. Meyer-Marcotti noted that compared to orthodontists and oral surgeons, laymen were equally able to detect asymmetries when located near the midline, and they believed asymmetries of the nose to be more negative than those of the same degree of the chin.\textsuperscript{15} The increasingly educated and perceptive public has helped develop the current soft tissue paradigm shift and an increased focus on facial symmetries as determined by photography.

The facial frontal smile photograph is used to assess “mini-esthetics.” These include an assessment of gingival display, tooth display, gingival heights, and buccal corridors.\textsuperscript{6} Along with attention to the soft tissue treatment objectives, mini-esthetics are routinely a portion of the patient’s chief complaint. Smile arc and buccal corridors have become part of the layperson orthodontic focus and research has been dedicated to
layperson’s perspective of these dental characteristics.\textsuperscript{16} As defined by Sarver and depicted in Figure 2.3, the smile arc is defined by the curvature of the maxillary incisal edges being consonant to the curvature of the lower lip.\textsuperscript{17} Buccal corridors exist when the transverse dimension of the maxillary dentition is deficient in relation to the adjacent soft tissue. Black shadows appear in the lateral segments of the smile giving an unaesthetic appearance.

Figure 2.3: The smile arc

In addition to the frontal smile, the oblique/45 degree smile photo studies the relationship between the occlusal plane and curvature of the lower lip (i.e., the smile arc). Sarver’s research focused on the smile arc from the frontal point of view. However, Springer et al. defined the ideal smile arc as one where the occlusal plane is consonant with the curvature of the lower lip in an anterior to posterior direction.\textsuperscript{18} Therefore, according to Springer the oblique smile photo is necessary to critique the smile arc.
The profile photo is used to assess facial convexity, nose and chin protrusion and the anterior-posterior relationship between the maxilla and mandible. Orthodontic skeletal diagnosis has long been, and continues to be, based on cephalometric radiographs. A facial profile photo allows the analysis of the face from the same perspective as the lateral cephalometric radiograph, only its purpose is soft tissue evaluation. The maxillo-mandibular relationship, chin projection and/or retrusion, lip competence and any other lateral soft tissue views may be studied from the profile photograph. Although skeletal dimensions may not be determined from a facial photograph, in many cases skeletal discrepancies are evident on the photos.

Figure 2.4: Facial outlines depicting Class I, Class II and Class III profiles

Figure 2.4 displays Class I, Class II, and Class III facial profiles. Although maxillary and mandibular dimensions are not known, the type of skeletal disharmony is evident.
In 1899, Edward Angle defined ideal dental occlusion based on the maxillary and mandibular first molars. Because the lower arch is somewhat smaller than the upper, the labial and buccal surfaces of the teeth of the upper jaw slightly overhang those of the lower. In normal occlusion the mesio-buccal cusp of the upper first molar is received in the sulcus between the mesial and distal buccal cusps of the lower. The slight overhanging of the upper teeth brings the buccal cusps of the bicuspids and molars of the lower jaw into the mesio-distal sulci of their antagonists, while the upper centrals, laterals, and cuspids overlap the lower about one-third the length of their crowns. Figure 2.5 shows Angle’s ideal Class I dental occlusion from the lateral and frontal perspective. Vertical lines on the maxillary first molar clearly demonstrate its relationship of the mesial buccal cusp resting in the embrasure of the buccal groove of the mandibular first molar.

Figure 2.5: Class I dental occlusion (adapted from Angle)
The maxillary central and lateral incisors are larger in height and width than their mandibular antagonists. As seen in Figure 2.6, they overlap the lower about one-third the length of their crowns and extend beyond them distally overlapping about one-half of the opposing mandibular lateral incisors.\(^{19}\)

![Figure 2.6: Class I dental relationship as viewed from the (A) lateral and (B) frontal views](image)

The first molars are also the reference point for defining Class II and Class III malocclusion. A Class II malocclusion exists when the lower first molar is positioned distally relative to the upper first molar. In most cases a Class II dentition will exhibit maxillary incisors in a forward position relative to the lower incisors (Figure 2.7) with the presence of an overjet.
Class II malocclusions are further defined by the relationship of the anterior segments. A Class II division 1 malocclusion has the upper incisors more proclined in relation to the remainder of the maxillary dentition establishing a positive overjet while a Class II division 2 malocclusion presents with retroclined central incisors (Figure 2.8).

Class III malocclusion exhibits a mandibular first molar mesially positioned relative to the maxillary first molar (Figure 2.9). Most often the maxillary incisors in a Class III
malocclusion are behind the mandibular incisors and termed “negative overjet.” Both Class II and Class III malocclusion are defined when at least one side of the dentition exhibits the molar relationship.

Figure 2.9: Class III molar and incisor relationships

Cephalometrics

Although one of the objectives of this study is to analyze the possibility of treatment planning without the aid of cephalometric radiographs, it is important to review at least a few of the many cephalometric analyses currently in use.

In 1931 radiographic cephalometry was introduced to the United States via a publication in the Angle Orthodontist by Broadbent. Since its introduction the lateral cephalometric radiograph has become a standard tool in orthodontic diagnosis and treatment planning. The basis of Broadbent’s design was a constant focal-spot-to-object distance and approximately 5 centimeter object-to-film distance. Modern day cephalometric radiographs are taken with the ear rods placed on both ears and the head in
natural head position. Natural head position is a standardized and reproducible
orientation of the head in space when one is focusing on a distant point at eye level.\textsuperscript{21}
The focal spot of the x-ray is directed through the patient’s midsagittal plane and
produces a lateral two-dimensional x-ray film of the patient’s head. Orthodontic
standards include skeletal evaluation by way of radiographic cephalometry. The x-ray
provides information as to skeletal size, position, proportion and symmetry of the
individual by which it is possible to assess skeletal disharmonies. A facial photograph
will represent, in most cases, soft tissue discrepancy. However, skeletal discrepancies
and soft tissue discrepancies may not be the same. Figure 2.10 from left to right
represents Class I, Class II, and Class III soft tissue profiles and skeletal discrepancies.
In this example soft tissue and skeletal discrepancies are matched. However, a Class I
soft tissue profile is not always associated with a Class I skeletal and dental relationship.
Cephalometric radiographs enhance orthodontic diagnosis and treatment planning through linear and angular measurements of the maxilla, mandible, and associated dentition. For this reason orthodontists began utilizing cephalometric analyses whereby the average facial pattern was used as the “norm” to compare each patient. However, when treatment decisions based on measurements obtained from individual tracings become dogmatic one must remember all tracings must be interpreted independently and then compared to the average facial pattern. One cannot expect facial patterns of orthodontic patients to conform to an average when individuals with normal occlusion differ from that average.

In 1948 Downs introduced one of the first cephalometric analyses to the orthodontic specialty. His objective was to develop a method of describing the nature of the facial skeleton pattern of normal occlusion and the manner in which the denture fits into it. Downs believed that if the normal pattern and its range of variation could be
described, then the abnormal one could be determined by comparison.\textsuperscript{22} Downs located the Frankfort horizontal, the plane connecting porion and orbitale and used it as the plane of reference by which all radiographs and photographs would be judged. From this plane he defined three anterior-posterior facial types based on his “facial angle” (Figure 2.11) in order to categorize all patients.

![Facial Angle Diagram](image)

Figure 2.11: The facial angle

The facial angle is defined by Frankfort horizontal and a line connecting hard tissue nasion and hard tissue pogonion. Analysis of the angle defined the relative position of the mandible to the maxilla as retrognathic, mesognathic or prognathic. Following Downs’ publication of his cephalometric analysis many variations were developed as alternatives to analyze cephalometric radiographs.
Steiner Analysis

During the 1950s Steiner developed his cephalometric analysis focusing on various parts of the skull; specifically, the skeletal, dental and soft tissue profiles.²¹ A major influence on Steiner’s orthodontic work was provided by Reidel. Prior to Steiner’s publication Reidel studied patient cephalograms of various ages and malocclusions with a focus on the relationship of the maxilla to the cranium and mandible. Reidel identified the most anterior points of the maxilla and mandible and labeled them A-point and B-point, respectively. Although most orthodontists of the time believed the ideal plane of reference was Frankfort horizontal, Reidel believed that porion and orbitale were traditionally used as a reference point because anthropologists had used the landmark to analyze dry skulls and the points were easily identified.²³ However, he felt there was too much error associated with their identification as the primary facial plane to reference his analysis. Therefore, he made the anterior cranial base, sella to nasion (SN), as his plane of reference. From SN, Reidel drew a line from A-point and B-point to create the angles SNA and SNB. These angles enabled Reidel to analyze the maxilla and mandible independently, and the discrepancy between the jaws with the ANB angle. Finally, Reidel focused on the mandibular plane angle by taking a line connecting Gonion (the most convex point on the inferior border of the mandible) and Gnathion (the midpoint between pogonion and menton) and extended the line to the SN line creating the mandibular plane angle (Figure 2.12).
Steiner was highly influenced by Reidel and utilized his findings as part of his analysis.

Figure 2.13 shows SNA and SNB angles utilized by both Reidel and Steiner. Along with these two angles Steiner focused on ANB and SNGoGn as the centerpiece of his analysis with the following averages: SNA 82°, SNB 80°, ANB 2°, and SNGoGn 32°.\textsuperscript{24} Discrepancies from the norm defined the associated jaw as deficient or excessive depending on the value of the angles and the appropriate skeletal classification was applied. Steiner also emphasized the value of interpreting all aspects of the analysis and not simply reading the numbers. An ANB exceeding 2° did not always mean a protrusive maxilla and a Class II dental relationship. If the SNA angle was within its normal limits (82° +/-3.9°)\textsuperscript{24} most often the mandible was deficient which could be verified by the SNB angle.
In order to graphically represent how his patients were different from the cephalometric “norms” previously established, Steiner created chevrons representing the ideal and acceptable compromises from the ideal (Figure 2.14).

Figure 2.14: Normal and acceptable compromises for Steiner’s chevrons (adapted from Steiner’s Cephalometrics in Clinical practice)\textsuperscript{25}

His method of analysis outlined the norms as the following: ANB: $2^\circ$, Maxillary central incisor to NA: 4mm and $22^\circ$, Mandibular central incisor to NB: 4mm and $25^\circ$. The
Steiner analysis creates a baseline chevron for each patient and acceptable compromises are filled in based on realistic treatment objectives and goals.

**Tweed Analysis**

Angle is widely recognized as the father of orthodontics due to his creation of what is now the modern day edgewise appliance. He believed an orthodontic appliance should have four properties: 1. simplicity 2. efficiency 3. delicacy 4. inconspicuousness. In 1928, just two years before he died, the Angle System was introduced to the orthodontic world and consisted of a horizontal 0.022 x 0.028 inch slot. Due to his untimely death he had little time to introduce and teach the mechanisms of his system and it was up to his successors to advance the appliance. Prior to his death Angle spent 7 weeks working with Tweed developing the Angle System appliance. Between 1928 and 1932 Tweed held firmly to Angle’s belief that teeth should never be extracted and a person should present with a full complement of teeth. However, in following his patients’ post-orthodontic treatment he was discouraged by the amount of relapse he observed. For 4 years Tweed devoted his time in studying why his cases were experiencing so much relapse and determined his most important observation; upright mandibular incisors frequently were related to post treatment facial balance and successful treatment.

Prior to Tweed’s cephalometric analysis publication in 1954 he attended a cephalometrics course taught by Moore, Wylie, Downs and Reidel to better understand the influence of cephalometrics on treatment outcomes. Following the meeting Tweed began focusing his attention on how cephalometrics would aid his diagnosis and
treatment planning, rather than using cephalometrics as a timeline for growth and development. He gathered a sample of four cases he treated in which he felt facial esthetics were pleasing and focused on angles he believed to be important in a successful orthodontic outcome. These angles are Frankfort plane to mandibular plane angle (FMA), Frankfort-mandibular incisor angle (FMIA), and incisor-mandibular plane angle (IMPA), otherwise known as the “Tweed Triangle” (Figure 2.15).

![Figure 2.15: The Tweed Triangle](image)

Taking the average of the 3 angles from cases he believed were the best clinical outcomes he determined ideals for the three angles: FMIA 65°, FMA 25°, and IMPA 90°.

In 1960 Tweed selected Merrifield, one of his outstanding students, to continue his work teaching the edgewise mechanism. For ten years prior to Tweed’s death he and Merrifield continued Tweed’s cephalometric studies and incorporated a soft tissue
analysis as part of their focus. The Tweed Triangle norms became the standard of care for all patients treated with the Tweed-Merrifield technique. However, they felt soft tissue chin and lip thickness may mask skeletal and/or dental disharmonies. Tweed believed the upper lip thickness should equal the total chin thickness and to analyze facial balance he created the profile line. A line tangent to the chin and vermilion borders of both the upper and lower lips and should lie in the anterior one third of the nose when facial balance is present (Figure 2.16).

Moreover, in order to connect the profile line with a component of the Tweed Triangle, Merrifield created the Z angle (Figure 2.17). Represented by the angle between Frankfort plane to the profile line, the Z-angle enabled Merrifield 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.²⁸

Figure 2.17: The Tweed-Merrifield Z-angle (adapted from Merrifield)²⁸

McNamara Analysis

In 1984 McNamara outlined a method of cephalometric evaluation based on five major sections:²⁹

1. Maxilla to cranial base
2. Maxilla to mandible
3. Mandible to cranial base
4. Dentition
5. Airway

McNamara considered two factors when assessing the maxilla to the cranial base: the first is the skeletal relationship of point A to the nasion perpendicular, and the second is
the patient’s soft tissue profile. A vertical line is drawn inferiorly from nasion through a perpendicular point at Frankfort horizontal. McNamara determined the average distance of point A from nasion perpendicular to be 1.0mm for well balanced faces of both male and female patients. Secondly, in a soft tissue evaluation of the maxilla to the cranial base the average nasolabial angle, as formed by drawing a line tangent to the base of the nose and a line tangent to the upper lip, should be 102° (+/- 8°).

The maxilla to mandible relationship exists based on the difference of lengths between the linear measurements between two points: condylion to point A and condylion to anatomic gonion. McNamara devised a table (Table 2.3) whereby all maxillary lengths correspond to an effective mandibular length within a range.
Table 2.3: Normative standards for comparison of the maxillary and mandibular lengths
(adapted from Jacobson)\textsuperscript{21}

<table>
<thead>
<tr>
<th>Midfacial Length (mm) (Co-Point A)</th>
<th>Mandibular Length (mm) Co-Gn</th>
<th>Lower Anterior Facial Height (mm) (ANS-Me)</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>97-100</td>
<td>57-58</td>
</tr>
<tr>
<td>81</td>
<td>99-102</td>
<td>57-58</td>
</tr>
<tr>
<td>82</td>
<td>101-104</td>
<td>58-59</td>
</tr>
<tr>
<td>83</td>
<td>103-106</td>
<td>58-59</td>
</tr>
<tr>
<td>84</td>
<td>104-107</td>
<td>59-60</td>
</tr>
<tr>
<td>85</td>
<td>105-108</td>
<td>60-62</td>
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<tr>
<td>86</td>
<td>107-110</td>
<td>60-62</td>
</tr>
<tr>
<td>87</td>
<td>109-112</td>
<td>61-63</td>
</tr>
<tr>
<td>88</td>
<td>111-114</td>
<td>61-63</td>
</tr>
<tr>
<td>89</td>
<td>112-115</td>
<td>62-64</td>
</tr>
<tr>
<td>90</td>
<td>113-116</td>
<td>63-64</td>
</tr>
<tr>
<td>91</td>
<td>115-118</td>
<td>63-64</td>
</tr>
<tr>
<td>92</td>
<td>117-120</td>
<td>64-65</td>
</tr>
<tr>
<td>93</td>
<td>119-122</td>
<td>65-66</td>
</tr>
<tr>
<td>94</td>
<td>121-124</td>
<td>66-67</td>
</tr>
<tr>
<td>95</td>
<td>122-125</td>
<td>67-69</td>
</tr>
</tbody>
</table>

In assessing anterior-posterior discrepancies McNamara stresses measuring both the midface and mandibular lengths, comparing to norms, and defining the disagreement. To assess vertical relationships between the maxilla and mandible he utilizes Frankfort Horizontal to the mandibular plane (FMA) (an average of $22^\circ \pm 4^\circ$)\textsuperscript{21} and the facial axis
angle. The facial axis angle (Figure 2.18) is constructed between a line through the posterosuperior point of the pterygomaxillary fissure (PTM) connecting basion and nasion, and a perpendicular through gnathion. According to McNamara, in a well-balanced face the appropriate facial axis angle is 90°.

![The Facial axis angle](image)

Figure 2.18: The Facial axis angle

The mandible to cranial base relationship is determined by one measurement: the linear measurement of hard tissue pogonion to nasion through a perpendicular point at Frankfort horizontal. The measurement is the distance between the constructed line and hard tissue pogonion. Therefore, negative numbers correspond to a retrusive mandible and positive numbers correspond to an excessive mandible.

In assessing the dentition, McNamara focused on the maxillary and mandibular incisors (Figure 2.19). Parallel to nasion perpendicular, a line is drawn through A-point...
and the distance measured from this line to the facial surface of the maxillary incisor, with an average of 4-6mm. The mandibular incisor is measured in a similar fashion, only the constructed line travels from hard tissue pogonion through A-point, with an average of 1-3mm.

Figure 2.19: Position of the maxillary and mandibular incisors as measured from McNamara’s constructed reference lines (adapted from Jacobson)

The airway analysis is specific to the upper and lower pharynx widths. McNamara believes a constricted pharynx may cause airway impingement leading to heavy mouth breathing and associated malocclusions. The average upper airway width is 15-20mm and lower 11-14mm.

After the five sections of the McNamara analysis are complete a table is created to assess the problem list and formulate a treatment plan.
Related Studies and Purpose

Prior studies have demonstrated the influence treatment philosophy and diagnostic records have on orthodontic diagnosis and treatment planning.\(^5,30-35\) In 1977 Brown et al. evaluated 4 orthodontists’ responses to treatment necessity of 50 orthodontic patients using study models only. All 50 cases were studied three times at weekly intervals answering the following questions: was treatment necessary? why treatment was necessary? and, when should treatment begin? In 41 of the 50 cases (82%) it was thought by at least 1 examiner treatment was indicated, but disagreement existed among them why and when treatment should begin.\(^34\) Following Brown’s 1977 study Silling et al. focused on the value orthodontists placed on cephalometric radiographs in treatment planning orthodontic cases. Twenty-four orthodontists independently evaluated 6 cases, 3 with the radiograph and 3 without, and questionnaires were provided for each case focusing on treatment decisions and growth patterns. The authors demonstrated high or total agreement on treatment decisions with or without cephalometric radiographs; therefore, it may be necessary for orthodontists to reassess their routine use of cephalometric radiographs.\(^33\)

Brown and Silling were both able to demonstrate orthodontists’ confidence in treatment planning with limited diagnostic information. However, neither study distinguished between what was the most important aspect of the records. In 1991 Han et al. sought to evaluate how each record, when provided incrementally, contributes to treatment decisions.\(^31\) Pretreatment records of 57 orthodontic cases were evaluated on 5 different occasions by 5 separate orthodontists. The records were provided in the following stages: 1) Study models (S); 2) S + facial photographs (F); 3) S + F +
panoramic radiograph (P) 4); S + F + P + lateral cephalogram (C); 5) S + F + P + C +
tracing. A diagnostic standard (DS) was created for each case by each orthodontist based
on their evaluation at stage 5 and used to compare to treatment decisions rendered at the
other four stages. Overall the DS was achieved with study models alone in 54.9% of the
cases, study models and photographs 54.2%, study models, photographs and panoramic
x-ray 60.9% and study models photographs, panoramic x-ray and cephalometric
radiograph 59.9%. Similar to Brown et al.’s results 14 years prior, Han et al. showed
study models alone were sufficient in treatment planning cases almost 55% of the time
and the addition of a cephalometric radiograph decreased the DS by 1% compared to the
same records without a cephalometric radiograph.31

The same time Han et al. was evaluating treatment decisions relative to increases
in available diagnostic records, Atchinson et al. were focusing on the contribution of
radiographs to treatment plans. Thirty-nine orthodontists diagnosed and treatment
planned six cases using orthodontic records which included the study models, facial and
intra oral photographs, and medical and dental histories. Following the initial evaluation
the clinician requested any x-ray he desired and reported his gain in confidence of the
treatment plan. There were 741 radiographs ordered, of which 192 produced changes in
the diagnoses, and the lateral cephalometric radiograph was the most productive.5
Results showed that orthodontists were approximately 75% confident of their diagnosis
before reviewing any radiograph.

More recently Devereux et al. focused on the added value lateral cephalometric
radiographs provided to orthodontists’ treatment planning decisions. They compared
treatment plan changes in three groups of orthodontists who evaluated six cases on two
occasions, T1 and T2, with varying access to a lateral cephalometric x-ray (LC). One hundred ninety-nine participating orthodontists were divided into 3 groups. The groups were defined by the availability of the following records: 1) all records except LC for T1 and T2; 2) all records including the LC at T1, and all records without the LC at T2; 3) all records including the LC at T1 and T2. The authors reported that “for most treatment-planning decisions the availability of a lateral cephalometric x-ray and its tracing did not make a significant difference in any treatment-planning decision.”

Prior research has demonstrated a cephalometric radiograph is not always indicated for self-assurance when diagnosing and treatment planning. To this point, studies have not shown treatment plan consistency when evaluating the same case with and without a cephalometric radiograph. The aim of the current study is to evaluate reliability of determining skeletal and dental relationships and consistency of diagnosing and treatment planning with and without a cephalometric radiograph.
References


CHAPTER 3: JOURNAL ARTICLE

Abstract

Introduction: The cephalometric radiograph has been a staple in orthodontic diagnosis and treatment planning since its introduction by Broadbent in 1931. Many analyses have been created by which to compare skeletal and dental relationships. Little research has been performed evaluating how valuable a cephalometric radiograph is in diagnosing and treatment planning orthodontic patients with consistency. Purpose: The aim of this study was to focus on the value that orthodontists place on cephalometric radiographs when diagnosis and treatment planning on two separate occasions.

Materials and Methods: Ten faculty members from SLU CADE were chosen at random to evaluate 65 sets of orthodontic records excluding the cephalometric radiograph. Each participant evaluated 11 of the 65 total records, of which 6 had been treated by that doctor, and the remaining 5 by none of the participants. A questionnaire of various skeletal questions and treatment plan options was applied to each case. The responses to each case treated by the participants (named “internal data”) were analyzed separate from the 5 universal cases (named “external data”) providing two sets of data. Skeletal relationships were calculated for external data only in order to compare evenly between the participants. Consistency of questionnaire responses was based on Kappa agreement measures and rates >0.60 were deemed statistically significant. Results: All internal data with regards to planning the use of auxiliary appliances, the decision to extract, and if surgical treatment was indicated came back at least substantially consistent to the original treatment plans. Estimating the patients’ skeletal classification, planning the use of an auxiliary appliance, and whether surgical treatment was indicated were consistently
significant for the external data. **Conclusions:** Based on these findings it can be concluded that orthodontists are confident in diagnosing and treatment planning without the use of a cephalometric radiograph and are consistent in their treatment plan decisions for cases they have treated in the past. However, there is little consistency of treatment plan decisions between doctors for cases treated by an unknown orthodontist. Finally, skeletal-dental relationships cannot be determined without access to a cephalometric radiograph.
Introduction

Prior to initiating treatment orthodontists perform a comprehensive exam consisting of medical and dental history and an intraoral examination. Diagnostic records are collected which normally includes photographs, study models and panoramic and cephalometric radiographs. While photographs and study models offer no harm to the patient, standard orthodontic radiographs expose patients to varying levels of radiation. Although radiation levels experienced by dental radiographs are low\textsuperscript{1,2} when compared to medical radiation scans and everyday background exposures,\textsuperscript{3} there must be clinical justification for ordering radiographs. The American Dental Association believes “dentists should weigh the benefits of dental radiographs against the consequences of increasing a patient’s exposure to radiation” and practice the “as low as reasonably achievable” (ALARA) principle to minimize exposure to radiation.\textsuperscript{4} The primary purpose of the radiographic examination is to provide additional information that may not be evident clinically.\textsuperscript{5} Many orthodontic textbooks do not describe a radiograph protocol. Rather, they explain diagnosis and treatment plan benefits for periapical, bitewing, panoramic and cephalometric radiographs.\textsuperscript{6–9}

Since its introduction the lateral cephalometric radiograph has become a standard tool in orthodontic diagnosis and treatment planning.\textsuperscript{10} The x-ray provides skeletal size, position, proportion and symmetry of the individual by which it is possible to assess skeletal disharmonies. Orthodontists routinely compare cephalometric values of their patients to ideals created by various analyses.\textsuperscript{11–14} In 1986 Atchinson reported a 90% response rate by orthodontists who routinely take lateral cephalometric and panoramic
radiographs at the initial exam.\textsuperscript{15} However, there is little research showing the value orthodontist place on these radiographs for diagnosing and treatment planning.

As early as 1979 Silling et al.\textsuperscript{16} demonstrated high or total agreement on treatment decisions with or without cephalometric radiographs. More recently Devereux et al.\textsuperscript{17} focused on the added value lateral cephalometric radiographs provided to orthodontists’ treatment planning decisions. They compared treatment plan changes in three groups of orthodontists who evaluated six cases on two occasions, T1 and T2, with varying access to a lateral cephalometric x-rays (LC). The authors reported that “for most treatment-planning decisions the availability of a lateral cephalometric x-ray and its tracing did not make a significant difference to any treatment-planning decision.”\textsuperscript{17}

The aim of this study is to focus on the value that orthodontists place on cephalometric radiographs when diagnosis and treatment planning on two separate occasions. Participants were asked to evaluate orthodontic records, not including the cephalometric radiograph, and answer questions focused on skeletal relationships and treatment plan options. The null hypotheses were the following: 1) orthodontists need a lateral cephalometric radiograph in order to determine skeletal characteristics, and 2) orthodontists do not need a lateral cephalometric radiograph to consistently treatment plan extraction and auxiliary appliance use.

**Materials and Methods**

The purpose of the study is to evaluate how much value orthodontists place on cephalometric radiographs for diagnosis and treatment planning. Ten faculty members from the Saint Louis University Center for Advanced Dental Education (SLU CADE)
were chosen at random to evaluate orthodontic records not including a cephalometric radiograph. To be considered for participation they must have graduated from an accredited orthodontic residency program and begun teaching at the University prior to January 1, 2005. All faculty members meeting the above inclusion criteria were considered. Prior to participation a consent to participate form (Appendix A) was provided to each participant.

Sixty-five sets of patient records were obtained at random from the SLU CADE archives using inclusion criteria set forth by the research team. Computer software of digitally filed patient records were used to create lists of archived patients meeting the following inclusion criteria: the participating faculty member’s name, removal of braces prior to January 1, 2007, less than 8mm of crowding, no missing permanent teeth (not including third molars), no mutilated dentitions, no presence of or potentially impacted teeth (as determined by the panoramic x-ray), no mixed dentition cases, no surgical treatment rendered, and all patients should be between 11-19 years old with no exclusion based on race or gender. Any case in which traditional photographic and radiographic film records were present were scanned and digitized with Dolphin Imaging® software for consistency purposes. Pretreatment records including composite 8 photos, study models, and the panoramic x-ray were provided to the participants.

Each participant evaluated 11 total cases, of which 6 had been treated by that respective orthodontist and 5 by other orthodontists. The 6 cases specific to the participant were called “treated” and the other 5 termed “universal.” All participants evaluated the 5 universal cases along with their treated cases. A maximum of two hours
was allowed to answer the questionnaires and no information was provided regarding the

treatment history of the cases.

A questionnaire (Appendix B) made of various skeletal questions and treatment plan options was created and applied to all 65 sets of patient records. The questionnaire consisted of a total of 19 questions, 16 of which (84%) were original questions written and tested by the research team. The remaining 3 were adapted from Devereux et al.\textsuperscript{17}

All cephalometric landmarks and angles related to the questionnaire were drawn and measured on the pretreatment cephalograms by the principle investigator prior to faculty participation. The measurements were documented and termed “actual” for comparison purposes following data collection. All treatment decisions pertaining to the treated and universal cases were also documented and termed “actual.” All answers provided on the questionnaires were documented as “guesses.” Although question #5 on the questionnaire used the term “orthopedic appliance” it was made clear to each participant that may include any auxiliary appliance, not including inter or intraarch elastics. Each participant was also made aware the use of a MSI for treatment inferred “maximum anchorage” for question #17.

In order to test consistency of diagnosis and treatment planning with and without cephalograms the “actual” decisions were tested against the “guesses” for questions 1-6, 8-16, and 18. Although the research team felt the inclusion criteria for all the cases was indicative of the majority of orthodontic cases treated, reliability of determining skeletal relationships (questions 1-4) were analyzed for the universal cases only. The remaining questions were analyzed by charting participant responses. Data gathered from the
“treated cases” was termed “internal” and data gathered from the “universal cases” termed “external.”

Response rates were calculated and reported for questions 1-6, 8-16, and 18 by comparing “actual” treatment plan decisions to the participants’ guesses on the questionnaires. A scale was created based on Kappa agreement measures from Landis and Koch and can be seen in table 3.1. A range of 0.00-1.00 was used with 0.00 representing zero consistency and 1.00 representing perfect consistency.

Table 3.1: Agreement measure for internal and external frequency data (adapted from Landis and Koch)

<table>
<thead>
<tr>
<th>Response Rate</th>
<th>Level of Consistency</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.00-0.20</td>
<td>Poor</td>
</tr>
<tr>
<td>0.21-0.40</td>
<td>Low</td>
</tr>
<tr>
<td>0.41-0.60</td>
<td>Moderate</td>
</tr>
<tr>
<td>0.61-0.80</td>
<td>Substantial</td>
</tr>
<tr>
<td>0.81-1.00</td>
<td>Almost Perfect</td>
</tr>
</tbody>
</table>

Results

Response rates were calculated using the consistency between answers provided on the questionnaires compared to actual skeletal relationships determined by the PI prior to the study and treatment decisions documented in the treatment charts. Tables were created displaying matches between answers on the questionnaires to actual treatment decisions or measurements. Surgical treatment was not provided to any case within the sample. Response rates for the indication for surgery demonstrated how often the participants agreed surgery was not indicated. The decision was made by the research
team that response rates $\geq 0.60$ were considered statistically significant and labeled as either substantial or perfect depending on the value. All response rates $\leq 0.59$ were deemed inconsistent with respect to answering the question “can orthodontists consistently diagnose and treatment plan cases on two occasions with limited access to a lateral cephalometric x-ray?" 

**Internal Data**

All internal data with regards to planning the use of auxiliary appliances, the decision to extract, and if surgical treatment was indicated came back at least substantially consistent to the original treatment plans. The following response rates were recorded for the aforementioned areas: the decision to use an auxiliary appliance $= 0.78$ (substantial), the decision to extract $= 0.80$ (substantial), and the decision surgery was not indicated $= 0.92$ (perfect), and can be seen in tables 3.2, 3.3, and 3.4.

Table 3.2: Consistency of the decision to use an auxiliary appliance for internal data

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>8</th>
<th>9</th>
<th>10</th>
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<td>5/6</td>
<td>4/6</td>
<td>46/59</td>
</tr>
<tr>
<td>2</td>
<td>0.67</td>
<td>0.83</td>
<td>1.00</td>
<td>1.00</td>
<td>0.67</td>
<td>0.60</td>
<td>0.67</td>
<td>0.83</td>
<td>0.83</td>
<td>0.67</td>
<td>*0.78</td>
</tr>
</tbody>
</table>
Table 3.3: Consistency of the decision to extract for internal data

<table>
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<th>4</th>
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<td></td>
<td>6/6</td>
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<td>4/6</td>
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</tr>
<tr>
<td></td>
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<td>0.67</td>
<td>1.00</td>
<td>1.00</td>
<td>0.67</td>
<td>0.67</td>
<td>0.50</td>
<td>0.83</td>
<td>*0.80</td>
</tr>
</tbody>
</table>

Table 3.4: Consistency of the decision surgery is not indicated for internal data

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
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<th>10</th>
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<td>6/6</td>
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<td>54/59</td>
</tr>
<tr>
<td></td>
<td>0.83</td>
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<td>1.00</td>
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<td>1.00</td>
<td>1.00</td>
<td>0.67</td>
<td>1.00</td>
<td>0.83</td>
<td>*0.92</td>
</tr>
</tbody>
</table>

Responses for what influenced each participant’s treatment decisions can be seen in figure 3.1.

Figure 3.1: Most influential aspect of the records for all participants for internal data
The concern each participant had for anchorage for each case can be seen in figure 3.2.

![Anchorage Concerns](image)

**Figure 3.2: Anchorage concerns for all 10 participants for internal data**

Extraction decisions and patterns (if applicable) were compared at both time points for all participants’ “treated” cases and can be seen in appendix C.

**External Data**

Reliability of determining skeletal relationships was calculated for the external data since all participants evaluated the same 5 cases. Determining skeletal classifications without a cephalometric radiograph was considered reliable and the response rate was substantial at a value of 0.74. Determining the ANB angle, SN-GoGn

43
angle, and IMPA had rates of 0.60, 0.36, and 0.32, respectively. All responses for determining skeletal relationships can be seen in table 3.5.

Table 3.5: Response rates of skeletal relationships for external data

<table>
<thead>
<tr>
<th>Question</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<td>3/5</td>
<td>4/5</td>
<td>4/5</td>
<td>2/5</td>
<td>4/5</td>
<td>37/50</td>
<td>0.74</td>
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<tr>
<td>ANB Angle</td>
<td>4/5</td>
<td>3/5</td>
<td>3/5</td>
<td>2/5</td>
<td>3/5</td>
<td>4/5</td>
<td>4/5</td>
<td>2/5</td>
<td>3/5</td>
<td>2/5</td>
<td>30/50</td>
<td>0.60</td>
</tr>
<tr>
<td>SNGoGn Angle</td>
<td>3/5</td>
<td>1/5</td>
<td>2/5</td>
<td>2/5</td>
<td>1/5</td>
<td>1/5</td>
<td>2/5</td>
<td>1/5</td>
<td>2/5</td>
<td>3/5</td>
<td>18/50</td>
<td>0.36</td>
</tr>
<tr>
<td>IMPA Angle</td>
<td>2/5</td>
<td>1/5</td>
<td>2/5</td>
<td>2/5</td>
<td>4/5</td>
<td>1/5</td>
<td>1/5</td>
<td>1/5</td>
<td>1/5</td>
<td>1/5</td>
<td>16/50</td>
<td>0.32</td>
</tr>
</tbody>
</table>

The decision to use auxiliary appliances had a response rate at 0.66 (substantial) and can be seen in table 3.6.

Table 3.6: Consistency of the decision to use an auxiliary appliance for external data

<table>
<thead>
<tr>
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<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
<tr>
<td>Rate</td>
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<td>0.80</td>
<td>0.60</td>
<td>0.60</td>
<td>*0.66</td>
</tr>
</tbody>
</table>

The decision surgical treatment was not indicated had a perfect response rate of 0.88 and can be seen in table 3.7.

Table 3.7: Consistency of the decision surgery is not indicated for external data

<table>
<thead>
<tr>
<th></th>
<th>1</th>
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<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
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The decision to extract had a rate of 0.22 (poor) as shown in table 3.8. This demonstrates a 22% level of agreement for extractions between the examiner panel.
Table 3.8: Consistency of the decision to extract for external data

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Responses for what influenced each participant’s treatment decisions can be seen in figure 3.3.

![Figure 3.3: Most influential aspect of the records for all participants for external data](image)

The concern each participant had for anchorage for each case can be seen in figure 3.4.
Extraction decisions and patterns (if applicable) were compared between the participants’ responses and the decision made by the treating doctor (not participating in the study) and can be seen in appendix D.

Responses for whether the provided records were satisfactory to confidently diagnose and treat orthodontic cases without a cephalometric x-ray were the only instance in which all responses were charted together and can be seen in figure 3.5.
Figure 3.5: Responses for whether the provided records were satisfactory to confidently diagnose and treat orthodontic cases without a cephalometric x-ray

Discussion

The goal of the study was to determine if orthodontists could reliably diagnose and consistently treatment plan orthodontic cases without the use of cephalometric radiographs. All participants randomly chosen were faculty members at Saint Louis University Center for Advanced Dental Education and 9 of 10 were trained at the same university. All participants report routinely taking cephalometric radiographs as part of their initial diagnostic records.
The patients used in the study ranged from 11-19 years old and were comprised of Class I and Class II malocclusions. The age range and malocclusion type were believed to be indicative of the majority of orthodontic cases seen in private practice and SLU CADE. It was decided at the onset of the study not to disclose to the participants they had treated a portion of the patients to be evaluated. There was a concern that some or all of the participants may remember the “treated” cases thereby diminishing the value of the reliability measures. Following data collection no participant informed the principle investigator they recognized any of the records.

The discrepancy between the maxilla and mandible, the angle of the mandible to the cranial base and the angulation of the mandibular incisors are cornerstones in most orthodontic analyses. For this reason the skeletal questions were based on ANB, SNGoGn and IMPA to test if clinicians could reliably determine the angles without a cephalometric radiograph. For most orthodontists major treatment plan decisions such as the need for surgery, indications for extractions and basic biomechanical philosophies are decided upon based on the aforementioned angles. Overall there was low reliability for all participants in determining skeletal related questions for the universal cases without a cephalometric radiograph. However, the doctors were substantially reliable in determining a patient’s skeletal classification without the cephalometric radiograph. Should this finding be unexpected? Orthodontists study faces everyday and for many of them the differences between a retrusive, normal, and protrusive mandible are glaring.

The second focus of the study was to test consistency of treatment plan decisions with and without a cephalometric radiograph. Prior studies have focused on the value elements of diagnostic records have on treatment plan decisions.5,16–19 However, previous
literature has not focused on consistency of treatment plan decisions before and after treatment when a cephalometric radiograph is not provided at both time points. Are cephalometric radiographs valued so highly that a previous treatment plan would change without the radiograph’s presence?

Consistency of treatment decisions were based on the use of an auxiliary appliance (e.g. functional appliance, expander, headgear, forsus) and the decision to extract. Planning the use of an auxiliary appliance was consistent for internal and external data. In fact, doctors 3 and 4 had perfect consistency when planning the use of an auxiliary when comparing their own evaluations at the two time points. Both participants documented functional appliance use in their original treatment plans.

Consistency of extraction decisions were split between internal and external data with substantial consistency (0.79) for internal and poor consistency (0.22) for external. These findings raise two important questions regarding treatment decisions: 1. did the participants remember the “treated” cases? 2. does treatment philosophy play the highest role in treatment decisions when comparing orthodontists? As stated earlier not one participant mentioned any recognition of any case they evaluated. Therefore, according to this study it can be assumed they continue to consistently evaluate and treatment plan orthodontic cases with limited consideration for the cephalometric information. Another explanation for the discrepancy between internal and external data for extraction decisions may have to do with the sample size. Each “treated” case was analyzed on one occasion by one participant. Whereas, the “universal” cases were analyzed on 10 separate occasions by 10 different participants. The large variation in sample size
between the two sets of data may explain the discrepancy between internal and external data.

Pre-angulated ("straight-wire"), non-prescription ("Tweed-Merrifield mechanics"), Tip-edge® and Damon® are just a few in a large variety of philosophies orthodontists use to treat cases. Are treatment plans influenced by a practitioners philosophy? In this study the level of consistency was substantial within the examiners for extraction decisions and planning auxiliaries, and between the examiners for planning auxiliaries. However, the consistency between examiners in planning extractions for the universal cases was poor. This finding is similar to the one by Ribarevski et al.20 who demonstrated good agreement within examiners and poor between the examiners when extraction decisions were made on two occasions. Although both studies demonstrated poor reliability between examiners when extraction decisions are made on two separate occasions, an important factor would be that the treatment decision making did not consider patients’ complaints or expectations. Although patient autonomy is considered a new paradigm in treatment planning, Mortenson et al.21 demonstrated that parents and/or patients demonstrate little knowledge and rely on the professional advice. There was no record or evidence that treatment was influenced by patient autonomy.

Although surgical cases were excluded from the sample, the belief that surgical treatment was not indicated was highly significant for both internal and external data. Severe skeletal discrepancies are almost always evident without the aid of a cephalometric radiograph. According to this study even moderate skeletal discrepancies were identified without the cephalometric radiograph. The surgery decision question was included on the questionnaire to provide the participants with all possible treatment
options. The response rate was low for the need of surgery (16.9%); however, 7 of the 11 responses indicating surgery was the proper treatment were in response to 3 of the universal cases. More interesting, 4 of the 10 doctors reported they would provide surgical treatment for at least one of the internal cases. It is agreed that a lateral cephalometric radiograph is a reliable diagnostic record by which severe skeletal discrepancies may be accurately assessed. Yet, even without a radiograph these doctors believed surgical treatment was indicated. Is there a reason to be concerned that, in some cases, when planning orthodontic treatment doctors become more aggressive with limited diagnostic information?

What is the weight of skeletal, dental, and facial variables in treatment planning? 80% of the doctors responded with dental considerations having the most influence on their treatment decisions for the “treated” cases and 70% of the doctors for the “universal” cases. Therefore, although this study does not answer the question of whether or not treatment philosophy plays a major role in planning treatment, it can be inferred that most orthodontists consider dental relationships above skeletal and facial relationships when planning treatment.

When asked about their comfort level to diagnose an orthodontic case without a cephalometric radiograph 70% of the orthodontists believed they were able to satisfactorily diagnose and treatment plan orthodontic cases for at least 7 of the 11 cases. Given the data it is safe to say with regards to consistency for the internal cases most orthodontists can plan treatment without a cephalometric radiograph. It is important to remember that this study only included Class I and Class II orthodontic patients in which surgical treatment was never discussed. Therefore, it cannot be assumed this conclusion
is valid for all orthodontic patients. Moreover, there was low reliability in determining ANB, SNGoGn, and IMPA angles, all of which are centerpieces in most cephalometric analyses. Since there was not 100% agreement among all participants in relation to the records provided, it cannot be assumed that all orthodontists can consistently diagnose and treatment plan orthodontic cases without a cephalometric radiograph.
Conclusions

1. Orthodontists can consistently treatment plan the use of an auxiliary appliance, the decision to extract, and if surgical treatment is indicated without a cephalometric radiograph for cases they treated in the past.

2. Orthodontists can consistently treatment plan the use of an auxiliary appliance and if surgical treatment is indicated without a cephalometric radiograph for cases treated by other orthodontists.

3. A patient’s skeletal classification can reliably be determined without the use of a cephalometric radiograph.

4. The majority of orthodontists are confident in diagnosing and treatment planning without the use of a cephalometric radiograph.
Appendix A

Participant Informed Consent

You are being asked to take part in a research study conducted by Nicholas Azar, DMD, and colleagues because you have been a faculty member at SLU CADE and a practicing orthodontist for no fewer than 7 years. This consent document may contain words that you do not understand. Please ask the research study doctor or research study team to explain anything that you do not understand.

1. WHY IS THIS RESEARCH STUDY BEING DONE?

Past literature has shown clinicians’ ability to satisfactorily diagnose and treatment plan orthodontic cases with limited use of diagnostic records. In some cases, models alone showed a 55% response in feeling comfortable diagnosing and treatment planning cases. Moreover, in studies whereby clinicians were asked to treatment plan cases on multiple occasions at different time intervals with additional records being added at each time point, satisfactory responses typically peaked with the use of models and patient photos. For these reasons we are interested in the value we place on cephalometric radiographs and their associated tracings. We want to know if treatment plans are altered based on the inclusion and exclusion of these records. All data will be collected at SLU CADE and all 10 participants will be randomly chosen from faculty who fit the criteria listed in the above section.

2. WHAT AM I BEING ASKED TO DO?

Your role in this research is to answer questions provided to you based on 11 different sets of orthodontic start records, not including the cephalometric x-ray and its corresponding tracing and measurements. You may take as long or as short as you feel necessary to answer the questions. You may not leave the room while answering the questions and must answer all the questions for the questionnaire’s responses to be considered valid. When you enter the conference room on the second story of CADE there will be two boxes labeled “unanswered questionnaires” and “completed questionnaires.” Please take one stack from the “unanswered” box and use these to record your responses. At each station of records there will be a numerical heading on the records which you will write down next to the alphabetized heading on each one of your questionnaires. Once completed, please place all completed questionnaires in the “completed” box and exit the room. We request that you do not discuss the project and/or cases with any other faculty member or resident at SLU CADE.
3. HOW LONG WILL I BE IN THE RESEARCH STUDY?

Your only time involved in the research study is the time needed to answer all 11 questionnaire packets. You will have a 2 hour time limit and may not leave the conference room once you have begun.

4. WHAT ARE THE RISKS?

The only risk to you is loss of confidentiality of your responses. Your responses will be collected anonymously to minimize this risk.

The research team is willing to discuss any questions you might have about the risk.

5. ARE THERE BENEFITS TO BEING IN THIS RESEARCH STUDY?

You may not benefit directly from this research. However, the long-term potential benefit of the study may include decreased necessity to take cephalometric radiographs and a reduced exposure to radiation for the patient.

6. WHAT OTHER OPTIONS ARE THERE?

You may choose not to be in this research study.

7. WILL MY INFORMATION BE KEPT PRIVATE?

The results of the research study may be published but your name or identity will not be revealed and your record will remain private. In order to protect your information, Nicholas Azar will collect your anonymous responses along with his thesis chair. The chair will create 10 stacks of 11 questionnaires all with a specific letter coding (ie. first stack all have the letter "A" in the top left corner). Each record will have a number
coding on the top left corner and the subject will be asked to write the record's number coding next to their letter coding on each questionnaire.

The Saint Louis University Institutional Review Board (the Board that is responsible for protecting the welfare of persons who take part in research) may review your research study records. State laws or court orders may also require that information from your research records be released.

8. WHAT ARE THE COSTS AND PAYMENTS?

There are no costs to participant in this research study and there will be no reimbursement to participants.

9. WHAT HAPPENS IF I AM INJURED BECAUSE I TOOK PART IN THIS RESEARCH STUDY?

If you believe that you are injured as a result of your participation in the research study, please contact the research study doctor and/or the Chairperson of the Institutional Review Board as stated in section 10.

10. WHO CAN I CALL IF I HAVE QUESTIONS?

If you have any questions or concerns about this research study, or if you have any problems that occur from taking part in this research study, you may call Nicholas Azar at 314-740-3236

If you have any questions about your rights as a research participant or if you believe you have suffered an injury as a result of taking part in the research, you may contact the Chairperson of the Saint Louis University Biomedical Institutional Review Board (314-977-7744), who will discuss your questions with you or will be able to refer you to someone else who will review the matter with you, identify other resources that may be available to you, and provide further information as how to proceed.

11. WHAT ARE MY RIGHTS AND WHAT ELSE SHOULD I KNOW AS A RESEARCH STUDY VOLUNTEER?
Your participation in this research is voluntary. You may choose not to be a part of this research. There will be no penalty to you if you choose not to take part. You may leave the research study at any time. The research study doctor or research study staff will let you know of any new information that may affect whether you want to continue to take part in the research study.

12. AM I SURE THAT I UNDERSTAND?

I have read this consent document and have been able to ask questions and state any concerns. The research team has responded to my questions and concerns. I believe I understand the research study and the potential benefits and risks that are involved.

Statement of Consent

I give my informed and voluntary consent to take part in this research study. I will be given a copy of this consent document for my records.

_______________________________  __________________________
Consent Signature of Research Participant  Date

_______________________________
Print Name of Participant

I certify that I have explained to the above individual(s) the nature and purpose of the research study and the possible benefit and risks associated with participation. I have answered any questions that have been raised and the subject/patient has received a copy of this signed consent document.

_______________________________  __________________________
Signature of Principal Investigator  Date

_______________________________
Print Name of Principal Investigator
Appendix B

Participant Questionnaire

1) What is your skeletal classification of this patient?
   a. Class I
   b. Class II
   c. Class III

2) What do you believe the A-point-Nasion-B-point (ANB) angle is?
   a. Less than -4°
   b. Between zero and -4°
   c. Between zero and +4°
   d. Between +4° and +8°
   e. Greater than +8°

3) What do you believe the Sella-Nasion-Gonion-Gnathion angle (Sn-GoGn) is?
   a. Less than or equal to 26°
   b. Greater than 26° but less than or equal to 30°
   c. Greater than 30° but less than or equal to 34°
   d. Greater than 34° but less than or equal to 38°
   e. Greater than 38°

4) What do you believe the lower incisor to mandibular plane angle (IMPA) is?
   a. Less than or equal to 90°
   b. Greater than 90° but less than or equal to 100°
   c. Greater than 100°

5) Do you plan to use an orthopedic appliance as part of your treatment plan (eg. RPE, Functional Appliance, Headgear)?
   a. Yes
   b. No
6) Would you extract as part of the treatment plan?
   a. Yes
   b. No

7) Which aspect of the case is the most influential in your treatment plan?
   a. Skeletal characteristics
   b. Dental characteristics
   c. Facial characteristics

If yes to #6 answer the following questions about your extraction pattern. If no to #6, move on to #17

8) 4 first bicuspids
   a. Yes
   b. No

9) Maxillary 1st bicuspids and mandibular 2nd bicuspids
   a. Yes
   b. No

10) 4 second bicuspids
    a. Yes
    b. No

11) Maxillary 2nd bicuspids, Mandibular 1st bicuspids
    a. Yes
    b. No

12) Asymmetric bicuspid extraction pattern of your choice (eg. 3 first bicuspids, 1 2nd bicuspid)
    a. Yes
    b. No
13) Maxillary 1\textsuperscript{st} bicuspids, one mandibular incisor
   a. Yes
   b. No

14) Maxillary bicuspids only
   a. Yes
   b. No

15) Mandibular bicuspids only
   a. Yes
   b. No

16) Mandibular incisor only
   a. Yes
   b. No

17) How would you classify anchorage in this case?
   a. No anchorage concern
   b. A little anchorage concern
   c. Maximum anchorage

18) Does this patient require surgery to meet your ideal treatment plan?
   a. Yes
   b. No

19) Do you feel you were able to reach a satisfactory tx plan with the provided records?
   a. Yes
   b. No
Appendix C
Extraction Frequency Data for Treated Cases

Doctor 1 Kappa = 1.000

Doctor 2 Kappa = 1.000
Doctor 3 Kappa = 0.250

Doctor 4 Kappa = 0.333
Doctor 7 Kappa = 0.250

Doctor 8 Kappa = 0.000
Doctor 9 Kappa = 0.000

Max 1\textsuperscript{st} bi's, Man 2\textsuperscript{nd} bi's

4 1\textsuperscript{st} bicuspid

Non-Extraction

Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6

Doctor 10 Kappa = 0.667

4 1\textsuperscript{st} bicuspid

Non-Extraction

Case 1 | Case 2 | Case 3 | Case 4 | Case 5 | Case 6
Appendix D

Extraction Frequency Data for Universal Cases

Case 1: Non-Extraction

Case 2: Upper 4’s, Lower 5’s
Case 3: Non-Extraction

Case 4: Asymmetric bicuspид extraction pattern
Case 5: Non-Extraction

- 60% Non-Extraction
- 20% 1st bicuspids
- 10% 2nd bicuspids
- 10% Asymmetric bicuspid pattern
References


Nicholas Philip Azar was born on November 17, 1981, in Belleville, Illinois, to Dr. and Mrs. Mark C. Azar. In 2004 he received his undergraduate degree in biology from Wittenberg University in Springfield, Ohio. Following college he attended the University of Nevada, Las Vegas, where he received his Doctorate in Dental Medicine in 2009. He is currently a candidate for the degree of Master of Science in Dentistry at Saint Louis University Center for Advanced Dental Education where he will also receive his certificate as a specialist in the field of orthodontics. He married his wife, Jill Azar, on May 27, 2006, in St. Louis, MO, and they have three children: Joseph, Adelaide, and Jane.