Comparative Analysis of Traditional Radiographs and Cone Beam Computed Tomography Volumetric Images in the Diagnosis and Treatment Planning of Maxillary Impacted Cuspids

by

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THESIS

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DEDICATION

I would like to dedicate this thesis to my mother, Sandra Haney. Thank you for your unwavering love and support!

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ABSTRACT

OBJECTIVE:

This prospective study compared differences in the diagnosis and treatment planning of impacted maxillary cuspids using traditional two dimensional (2D) planar radiographs versus three dimensional (3D) volumetric images generated from cone-beam CT (CBCT) DICOM data.

MATERIALS AND METHODS:

Twenty-five consecutive impacted maxillary cuspids were identified from eighteen patients seeking orthodontic treatment at UCSF and enrolled in this study. For each case, two separate sets of radiographic information were obtained. The first set consisted of traditional images including a panoramic, occlusal, and two periapical radiographs. The second set was composed of prints of volumetric dentition images obtained from a CBCT scan. A questionnaire was developed to record diagnosis and resulting treatment plan derived from the 2D and 3D images obtained for each impacted tooth. Specific questions related to the location of the cusp tip, presence or absence of root resorption, the proposed orthodontic or surgical treatment plan, and an assessment of the confidence level of each diagnosis and treatment plan.

Of the seven UCSF diagnosticians who participated in this study, four were orthodontic and three were oral and maxillofacial surgery faculty. Three of the seven judges were senior faculty with more than 10 years of clinical experience, while four were categorized as junior faculty. Each faculty member completed a questionnaire for every impacted cuspid and diagnostic radiographic modality (2D and 3D). The patient data sets were presented in random order. The data from five cuspid cases were randomly selected for repeat evaluations for intra-examiner reliability.

RESULTS:

The data shows that the judges did alter their decision regarding localization to varying degrees based on the two different modalities. There was a 21% lack of congruence in the perceived mesial-distal cusp tip position, and a 16% difference in the perceived labial-palatal position. In the perception of root resorption of adjacent teeth, there was a 36% lack of congruence (45% for orthodontists and 26% for oral surgeons). Fifty three percent of the teeth that were treatment planned for extraction while using traditional radiographs were selected for recovery, rather than extraction, when viewing the CBCT images (McNemar test, chi-square=4.45, $p=0.035$). Eleven of the twelve teeth treatment planned for an initial distal recovery vector with the traditional 2D data set had a different recovery vector when treatment-planned using the CBCT data set. Sixty-five percent of initial recovery vectors were different for senior judges compared to 75% for junior judges when using the two different modalities (Fisher exact test, $p=0.013$). Additional images were requested for 34% of traditional images compared to 19% for the CBCT images (McNemar test, $p=0.02$). The surgeon's decision regarding the location of initial surgical access changed 16% between the two modalities. Confidence of the accuracy of diagnosis and treatment plan was statistically higher for CBCT images ($p<0.001$).

CONCLUSIONS:

These results suggest that the use of two-dimensional and three-dimensional images of the impacted cuspids in the maxilla can produce very different diagnoses and resulting treatment plans.

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INTRODUCTION

Most permanent teeth erupt into occlusion unassisted. Occasionally, however, some permanent teeth become impacted and fail to erupt. This situation often requires intervention by both an orthodontist and oral and maxillofacial surgeon. The treatment decision whether to recover, extract, or do nothing takes into account several factors. Some of these factors include: location of the impaction, prognosis of intervention on the impacted tooth and adjacent teeth, surgical accessibility, impact of treatment on the final functional occlusion, possible surgical morbidity. This treatment decision has traditionally been based on diagnosis based on planar two dimensional (2D) radiographs. New technology offers three dimensional (3D) volumetric images. This three dimensional technology may improve the dental provider's ability to diagnose and subsequently treat patients with impacted teeth. This study aims to determine if the use of two different imaging modalities, two dimensional and three dimensional, will result in a different diagnosis and/or a different treatment plan for impacted maxillary cuspids.

Impacted Teeth

Teeth normally erupt after ½ to ¾ of their root length has been developed. Teeth with delayed eruption are teeth whose roots are more completely developed, have not erupted, but are expected to erupt spontaneously in the future. Ectopic teeth are those which are positioned abnormally, erupted or not. Impacted teeth are those whose root development may be complete, but further eruption is not expected because the eruption path is blocked by an obstacle (Figure 1). In addition, an impacted tooth is one "whose eruption is considerably delayed, and for which there is clinical or radiographic evidence that further eruption may not take place". (Thilander and Jakobsson 1968)

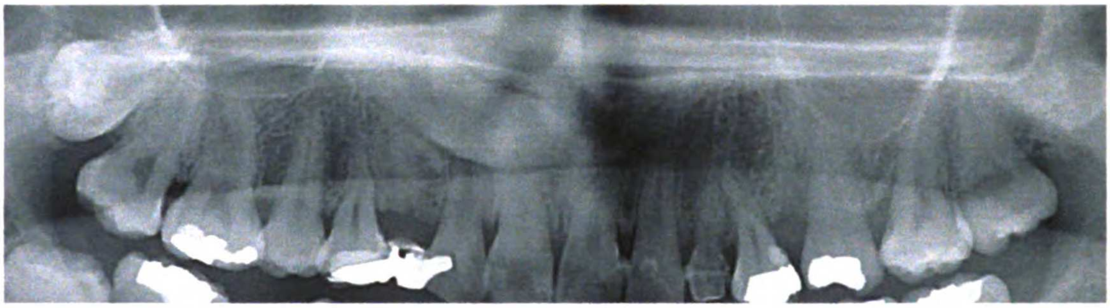

Figure 1. Panoramic radiograph of an impacted maxillary cuspid in one human subject.

Incidence of Impaction

The maxillary cuspid tooth is the second most commonly impacted tooth, after 3rd molars. Their reported incidence ranges from 0.8-2.8% depending on the population examined. (Dachi and Howell 1961; Thilander and Jakobsson 1968; Shah, Boyd et al. 1978; Grover and Lorton 1985; Ericson and Kurol 1987) It has been reported that the incidence of impactions are twice as likely in females.(Dachi and Howell 1961) Even though maxillary cuspid tooth buds develop labial to adjacent tooth roots, the ratio of palatal impactions to labial impactions has been found to be at least 3:1.(Fournier, Turcotte et al. 1982) Other investigators have found impacted cuspids to be positioned palatal 85% of time compared to a labial position 15% of the time. (Rayne 1969; Ericson and Kurol 1987) In addition, 8% of cuspid impactions are bilateral (Figure 2). (Bishara 1992)

Figure 2. Panoramic radiograph of bilateral impacted maxillary cuspids in one human subject.

Etiology

The etiology of impactions is obscure. Five etiological factors have been reported in the literature. These factors include: 1) ectopic position of tooth germs, 2) delayed eruption of deciduous teeth, 3) lack of adequate guidance along the roots of lateral incisors, 4) general systemic diseases, and 5) genetic influences.(Miller 1963/64; Bass 1967; Becker, Smith et al. 1981; Becker 1984; Bishara 1992; Baccetti 1998)

Maxillary cuspids have the longest period of development, deepest area of development, and most circuitous eruption path of all teeth. The normal eruption path of maxillary cuspids has been quantified. From age 5-10 years old, the cuspid will travel 22 mm. From 5-9 years old, cuspids tend to move palatally followed by a significant labial movement from age 10-12.(Coulter and Richardson 1997) This failure of labial movement has been implicated in palatal cuspid impactions.(Williams 1981) Jacoby found that 85% of palatally impacted cuspids had sufficient space for eruption into the dental arch, while only 17% of labially impacted maxillary cuspids had sufficient space.(Jacoby 1983) Peck and Peck reported that labial displacement and impaction of the cuspid was due to inadequate arch space, whereas palatal displacement was a positional anomaly that occurs despite adequate arch length.(Peck, Peck et al. 1994)

Lack of adequate guidance along the roots of the lateral incisors involves abnormal tooth bud eruption, abnormal eruption rate, and delayed resorption of deciduous teeth.

Genetic influences are apparent given that impactions are often associated with other dental abnormalities. It has been reported that 33% of patients with impacted cuspids have other congenitally missing or malformed teeth.(Peck, Peck et al. 1994) Also, the incidence of palatally impacted cuspids is twice as high for females.

Sequelae of Impactions

Shafer, in 1963, listed seven possible sequelae related to unerupted cuspids: 1) labial or lingual malpositioning of the tooth, 2) migration of adjacent teeth with loss of arch length, 3) internal resorption, 4) dentigerous cyst formation, 5) external root resorption of the impacted and/or neighboring teeth, 6) infection related to partial impaction, and 7) pain.(Shafer 1963) Still, the presence of the impacted cuspid may cause no untoward effects during the lifetime of the person.(Shafer 1963) However, these above mentioned potential complications emphasize the need for observation of the development and eruption of these teeth during periodic dental examinations.

Labially positioned ectopic cuspids may erupt on their own without surgical exposure or orthodontic treatment, while palatally impacted cuspids seldom erupt without intervention.(Jacoby 1983)

Impacted maxillary cuspids cause resorption of the central or lateral incisor roots in almost 50% of the cases. Root resorption is three times as common in girls as in boys. Resorption was consistently found in patients with a more advanced dental development, a cuspid cusp positioned more medially in the dental arch, or with a more mesial than normal eruption path. Width of the dental follicle and proclination or distal tilting of the lateral incisor showed no correlation to the resorption. Potential resorption cases are always those in which the cuspid cusp is positioned medially to the midline of the lateral incisor (Figure 3).(Ericson and Kurol 1988)

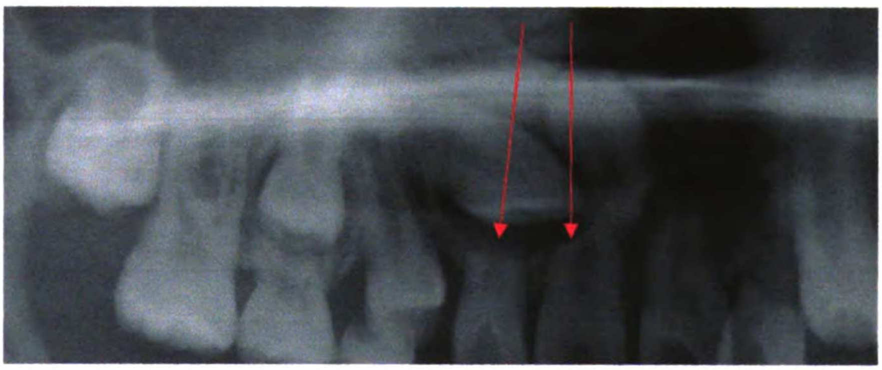

Figure 3. Panoramic radiograph with incisor root resorption due to the impacted cuspid.

Localization

Proper localization is required in order to make an accurate diagnosis, to determine proper surgical access and to plan the direction of orthodontic recovery forces.

In the past diagnostic radiographs included periapicals, occlusals (normal and topographical), and panoramic radiographs. In orthodontics, knowing the exact location of an impacted cuspid is paramount, since the decision whether the cuspid should be exposed, extracted, recovered, or left untreated may considerably influence the treatment plan.

In the case of a labial impaction, locating the tooth often can be accomplished with palpation. If the tooth is positioned in the middle of the alveolus or palatally, however, it will be necessary to determine its labial-palatal location by taking two or more periapical radiographs at different horizontal angles. Use of Clark's Rule enables the practitioner to determine the location of these impacted teeth. When radiographs are taken at different horizontal angulations of a pair of objects, the image of the palatal object moves in the same direction of the x-ray beam, while the labial object appears to move in the opposite direction (Figure 4).(Clark 1909) With this periapical film technique, the clinician is able to evaluate the labial-palatal position of the cuspid with sufficient accuracy in 92% of the cases.(Ericson and Kurol 1987)

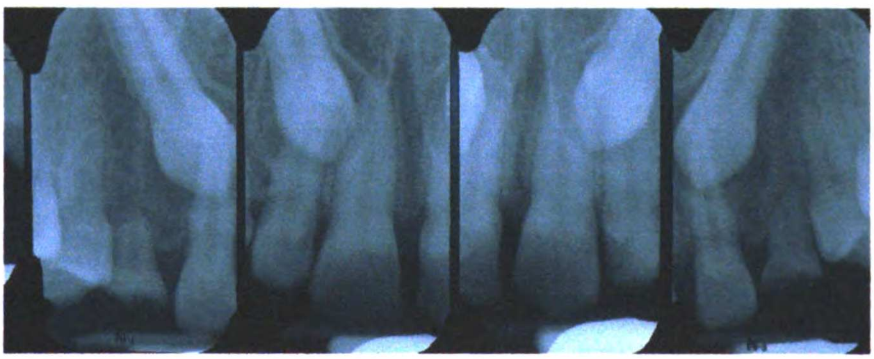

Figure 4. Periapicals of impacted cuspids, used to determine their labial-palatal position. Both cuspids are to the palatal of the lateral roots.

Additional radiographic images are often required to ascertain the exact location of an impacted tooth in all three dimensions. To aid in determining the vertical position and horizontal angulation, a panoramic radiograph is utilized (Figure 2). Normal occlusal and/or topographic occlusal radiographs help locate the proximity of adjacent teeth (Figure 5). In addition, they help determine the labial-palatal position of the impacted cuspid in conjunction with the periapical films, provided that the image of the impacted cuspid is not superimposed on the other teeth.(Langland and Sippy 1968) Frontal and lateral cephalograms often elucidate proximity to other facial structures such as the maxillary sinus and nasal floor (Figure 6).(Turk and Katzenell 1970)

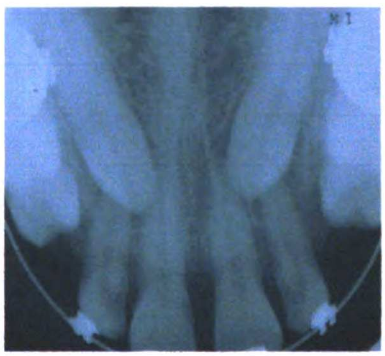

Figure 5. Maxillary occlusal radiograph of bilaterally impacted cuspids. This view does not indicate how close the cuspid crowns are to the incisor roots.

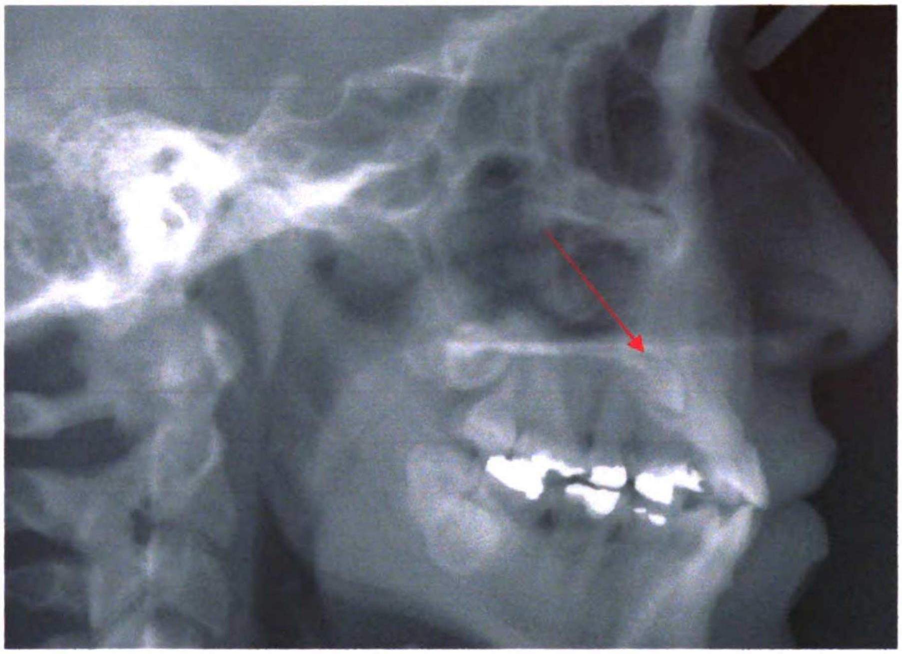

Figure 6. Lateral cephalogram, note the height and angulation of the maxillary impacted cuspid.

Prediction of a Future Impaction and Diagnosis

Predicting future impaction of maxillary cuspid is dependant on two significant factors: mesial-distal location and angulation of the cuspid crown. Ericson and Kurol (1987) reported the more a crown was mesially located, the decreased likelihood of normal eruption after deciduous cuspid extraction.(Ericson and Kurol 1987) Powers and Short (1993) looked at angulation as a predictor. They found that if the crown of the cuspids is greater than 31° to the vertical line at the midline, the chances of eruption after deciduous extraction are decreased.(Power and Short 1993) In another study, the mesial-distal position of an unerupted cuspid was evaluated from panoramic radiographs to predict its future impaction. It was reported that cuspids that become impacted will overlap the adjacent lateral incisor in 82% of cases. In addition, it has been found that when the cuspid overlaps the midline of the lateral incisor, there is a 87% chance of impaction.(Warford, Grandhi et al. 2003)

Diagnosis of an impacted maxillary cuspid is based on both the clinical and radiographic examination. Clinical signs of a cuspid impaction include: 1) delayed eruption of the permanent cuspid or prolonged retention of the deciduous cuspid beyond the age of 14-15 years old, 2) absence of the normal labial cuspid bulge, 3) presence of an abnormal palatal bulge, 4) delayed eruption, 5) distal tipping or splaying of the lateral incisor, 6) loss of vitality, or 7) increased mobility of the erupted permanent incisors.(Kettle 1958; Thilander and Jakobsson 1968; Ericson and Kurol 1986)

For patients younger than 10 years of age, the clinician should suspect that a palatal impaction may occur in the future if there is a family history of palatal cuspid impactions or the patient has small, peg-shaped, or missing lateral incisors. For patients 10 years or older, the clinician should suspect that an impaction may have occurred if there exists an asymmetry in palpation or a pronounced difference in eruption of cuspids between the left and right side, the cuspids can not be palpated labially and occlusal development is advanced, or the lateral incisor is proclined and tipped distally. Of note is that distal tipping alone may be the normal "ugly duckling" stage of dental development.(Ericson and Kurol, 1986)

Prevention

The most common preventive treatment to avoid cuspid impaction is to extract the deciduous cuspid earlier than normal and allow the permanent cuspid to self correct its unfavorable eruption path. Good success has been reported with this treatment, with more favorable eruption occurring 62-78% of the time. Extraction of deciduous cuspids in children as early as 8 or 9 years old is an interceptive approach to cuspid impaction in Class I uncrowded cases.(Williams 1981)

It has been suggested that the removal of the deciduous cuspid before 11 years of age would normalize the position of the ectopically erupting permanent cuspids in 91% of the cases, if the cuspid crown was distal to the midline of the lateral incisor. If the cuspid crown was mesial to the midline of the lateral incisor root, the success rate was only 64%.(Ericson and Kurol 1988)

Treatment Duration

Stewart looked at the relationship between the initial position of a palatally impacted cuspid and the duration of orthodontic treatment. He also investigated whether a difference in treatment duration existed between patients with bilateral palatally impacted cuspids and patients with a unilateral impaction. He found that the average duration of treatment was 22.4 months for the unimpacted group, 25.8 months for the unilateral impaction group, and 32.3 months for the bilateral impaction group. Length of treatment for the impacted cuspid sample was related to the age of the patient. The younger patients in the unilateral impacted group had more severely impacted cuspids. If the impacted cuspid was located less than 14 mm from the occlusal plane, treatment duration averaged 23.8 months. If the cuspid was located more than 14 mm from the occlusal plane, the treatment duration averaged 31.1 months. Stewart concluded that younger patients had longer treatment durations and more severely impacted cuspids. This may mean that impacted cuspids have some capacity to self-correct with time. Bilateral impactions took 6 months longer to treat, which could be because these impactions were more severe.(Stewart, Heo et al. 2001) However, Stewart conceded that research into factors that affect orthodontic treatment duration are still relatively new, and requires additional studies to more accurately determine the causes of variation in treatment time for all types of orthodontic malocclusions, including impacted cuspids.

Treatment Alternatives

There are several treatment options for impacted maxillary cuspids. One option is no treatment, retain the deciduous cuspid, and periodic evaluation to check for pathologic changes. Unfortunately, the long term prognosis of retaining a deciduous cuspid is poor, regardless of root length and esthetics. Eventually the root will resorb and the deciduous cuspid will have to be extracted.(Shaw 1981; Sayne 1986) Other options include auto transplantation with a bicuspid, extraction of the impacted cuspid and movement of a first bicuspid in its position or extraction of cuspid and posterior segmental osteotomy to move the buccal segment mesially to close the residual space.(Maloney 1985) Another option is to extract the impacted cuspid and replace with a prosthetic tooth. The most common treatment option is surgical exposure of the cuspid and orthodontic treatment to bring the tooth into the line of occlusion.(Bishara, Kommer et al. 1976)

According to Bishara, extraction of the labially erupting and crowded cuspid is contraindicated. Extraction may temporarily improve the esthetics but will compromise the final orthodontic treatment results, including a midline shift and the inability to provide a functional occlusion. Extraction of any impacted cuspid might be considered if the cuspid is ankylosed and cannot be transplanted, is undergoing external or internal root resorption, has a severely dilacerated root, or is a severely impacted, in which orthodontic movement may jeopardize the central and lateral incisors.(Bishara 1992) Extraction of the impacted cuspid is an option if the occlusion is acceptable with the first premolar in the position of the cuspid, and with an otherwise functional occlusion with well aligned teeth.(Bishara 1998) If the impacted tooth is extracted rather than repositioned, additional treatment may be required such as placing an implant or delivering fixed partial denture to replace the missing tooth.

Proactive treatment of an impacted maxillary cuspid needs to be integrated into the overall orthodontic treatment scheme, because usually adequate space in the arch must be regained for the cuspid. This requires moving adjacent teeth, either with or without extractions. In addition, other teeth in the same arch must provide the anchorage for the recovery forces applied to the impacted tooth.

Another option to manage a palatally impacted cuspid is just surgical exposure to remove obstructive tissue and allow subsequent natural eruption. This procedure removes just the bone and tissue along the existing eruption path resulting in a more rapid eruption rate. This technique should be employed only if the tooth has a favorable axial inclination and does not need to be uprighted during eruption. Once erupted, it will likely need orthodontic intervention and monitoring. One must monitor the progress with films containing reference points like adjacent teeth or an arch wire. Some disadvantages of this approach are slow cuspid eruption, increased treatment time, and inability to influence the path of eruption.

When surgically uncovering and orthodontically recovering an impacted tooth, one must consider the timing of orthodontic treatment, type of surgical procedure to uncover the impacted tooth, necessary orthodontic mechanics, and potential problems. The most common technique for recovery of impacted maxillary cuspids is surgical exposure, and bonding a gold chain to the tooth, and subsequent redirection by the orthodontist.(Lewis 1971)

Retention

Becker evaluated the post-treatment alignment of previously impacted cuspids in patients whose orthodontic treatment had been completed. He found 17.4% of the cases had increased incidence of rotations and spacing on the impacted side compared to 8.7% on the control side. He also found that the control side had ideal alignment twice as often as the impacted side. This indicates that total orthodontic correction can be difficult.

In order to minimize rotational relapse, a fiberotomy or a bonded fixed retainer may be considered after completion of movement and before the appliances are removed.(Becker and Chaushu 2003) It has also been suggested that after the alignment of palatally impacted cuspids, lingual drift can be prevented by removal of a "halfmoon-shaped wedge" of tissue from the lingual aspect of the cuspid.(Clark 1971)

Cone Beam Computed Tomography

Orthodontics and oral surgery has always had a need for precisely locating teeth and tissue in all three planes of space. To date only planar radiographs have been available. This information has been available through use of a medical X-ray CT scanner, but limitations include, image resolution, exposure dose, cost, and logistics. A new system, cone-beam computed tomography (CBCT) also known as cone-beam volumetric tomography (CBVT), has been developed by Hitachi specifically designed for three dimensional imaging of the craniofacial field. The unique feature of this system is that it uses a low energy fixed anode tube which produces a cone-shaped x-ray beam, a special image intensifier, and a solid state sensor or an amorphous silicon plate for capturing the image. Conventional medical CT devices image patients with a high output rotating anode generator in a series of axial plane slices that are captured either as stacked slices or from a continuous spiral motion over the axial plane, consequently, using a fan-shaped x-ray beam. Conversely, CBCT requires only a single 360° rotation sweep of the patient, similar to the path panoramic radiography. Image data can be collected for either a complete dental or maxillofacial volume or a limited regional area of interest.(K Seo 2000) (Figure 7) Images are reconstructed from the acquired radiographic data.

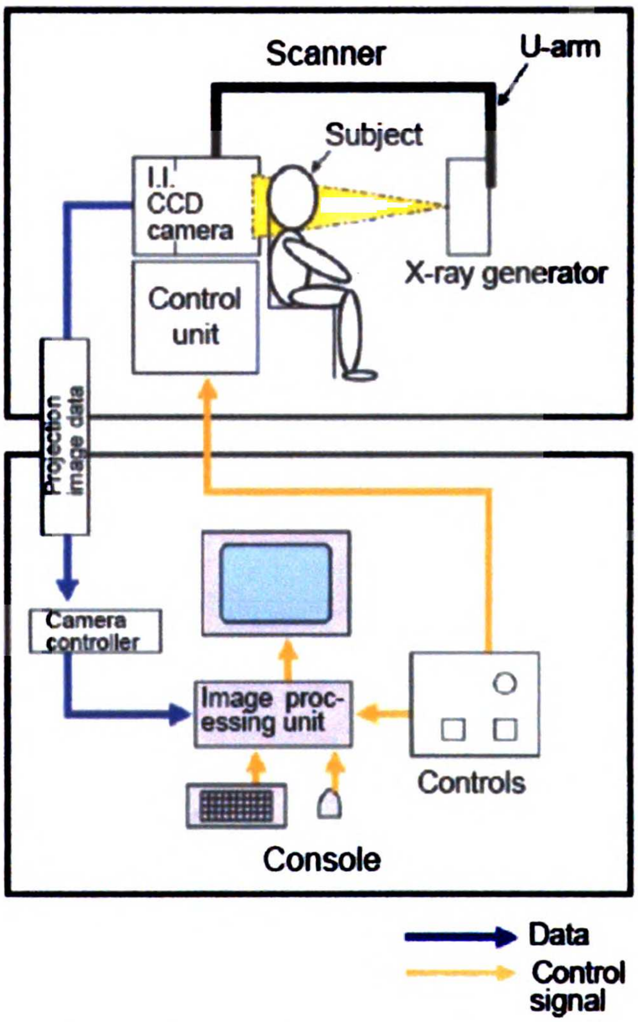

Figure 7. Schematic diagram of Hitachi CB MercuRay.

CBCT images are inherently more accurate due to the fact that the beam projection is orthogonal, which means that the x-ray beams are approximately parallel to one another and the object is very near the sensor. This explains why there is very little projection effect. In addition, this effect is handled by the computer software, resulting in undistorted 1-to-1 measurements. This is in contrast to traditional imaging where there is always some projection error because the anatomic region of interest is some distance away from the film. For example, panoramic radiographs have an unusual projection error because the main path of the x-ray beam comes from a slight negative angulation. In this situation the dental provider must account for these imaging artifacts when reading the images.

Another likely advantage of the CBCT scan is that the data acquired includes information for the entire craniofacial region. Additional views such as lateral cephalogram, panograms, occlusals, airway evaluation, and new volumetric images are available if desired from the original acquisition data. (Jolley 2006; Sears 2006) In addition these images can be manipulated with imaging software to aid the dental provider in diagnosis and treatment planning. The costs, efficiency, and benefits of CBCT imaging are very favorable, because one imaging session provides multiple views.(Mah and Hatcher 2004)

Rationale and Significance

Using traditional radiographs, orthodontists and oral surgeons may have insufficient information to make an accurate diagnosis and a proper treatment plan. This could lead to an incorrect surgical access path when exposing the impacted cuspid and incorrect orthodontic recovery vectors which may jeopardize adjacent teeth and/or the impacted cuspid. Proponents of 3D CBCT radiography claim diagnosis and treatment planning is easier & superior to traditional 2D radiography. This paper will attempt to determine if there a clinically significant difference in the diagnostic value of cone beam technology. It will also investigate if there is a difference in the subsequent orthodontic and surgical treatment plans.

Overall Objective

The overall objective of this study is to test the diagnostic value of cone beam computed tomography versus traditional planar radiographs.

Specific Aim #1

To compare the ability of orthodontists & oral surgeons to precisely diagnosis impacted cuspids using traditional two dimensional radiographs versus three dimensional cone-beam images. Is there a difference diagnosed cuspid tip location or root resorption of adjacent teeth?

Specific Aim #2

To compare treatment plans of orthodontists using traditional two dimensional radiographs against those using three dimensional CBCT images. Is there a difference in orthodontic treatment plans and recovery vectors?

Specific Aim #3

To compare treatment plans of oral surgeons using traditional two dimensional radiographs vs. those using three dimensional CBCT images. Is there a difference in surgical approach, techniques or access to the impacted cuspid?

Specific Aim #4

To compare differences in diagnosis and treatment planning based on clinical experience of the individual orthodontist and oral surgeon.

Method and Materials

Eighteen consecutive patients (12 female, 6 male) with impacted maxillary cuspids were identified in the orthodontic clinic at the University of California at San Francisco (UCSF). Twenty five impacted cuspids were evaluated, which included seven bilateral impactions. Six were right unilateral and five were left unilateral. The subjects ranged in age from 12.3 to 34.6 years with a mean of 16.9 years and a standard deviation of 5.8 years. Exclusion criteria included presence of any deciduous teeth, craniofacial anomalies, incomplete root formation, and the presence of orthodontic appliances. For each subject, traditional two dimensional diagnostic radiographs and a cone beam computerized tomography (CBCT) data scans (Hitachi MercuRay, Hitachi Medical Technology, Tokyo, Japan) in DICOM form were obtained.

The traditional radiographs included a panogram to evaluate the vertical position, an occlusal to evaluate the proximity to adjacent teeth, and two periapicals to determine the labial-palatal position. Volumetric images of the maxillary dentition were obtained from a CBCT scan. CBWorks software (CyberMed Inc., Seoul, Korea) was utilized for the segmentation process. The volume operation and sculpt feature omitted all soft tissue and hard tissue excluding the maxillary dentition. Segmentation of the maxillary dentition was performed by a single operator. Three dimensional images included anterior, posterior, rostral-caudal, caudal-rostral, labial, and palatal views. The images were illustrated on a single sheet of glossy photo paper (Epson, Long Beach, CA). All identifying patient information was eliminated, including patient name, sex, age, and race.

This study was approved by the UCSF Institutional Review Board, the Committee on Human Research, under an umbrella CBCT research approval, which included minors. Informed consent to participate in this study was obtained from each subject or, in the case of minors, guardian.

Two questionnaires were developed with the assistance of the orthodontic and oral and maxillofacial surgery faculty at the University of California at San Francisco (see Appendix 1 and 2). The first questionnaire was specific for orthodontists and the second questionnaire was specific for oral and maxillofacial surgeons. The questionnaire was designed to answer questions regarding localization of the impacted cuspid in all three planes of space, presence of root resorption on adjacent teeth, orthodontic treatment plan (i.e., recover, extract, or leave), surgical access and flap design, recovery vectors if applicable, request for additional images, and confidence of the determined diagnosis and treatment plan.

A pilot study was performed with four orthodontic residents and two oral and maxillofacial surgery residents at the University of California at San Francisco. The aim of the pilot study was to validate and refine the questionnaire.

Each presentation of the impacted maxillary cuspids was randomly ordered throughout the UCSF orthodontic clinic with the use of a random number generator (www.randomizer.org). In addition, five impacted maxillary cuspids were randomly selected for replicates and were randomly interspersed to be evaluated a second time to evaluate intra-operator reliability. A total of sixty stations were prepared which included thirty traditional two-dimensional radiographs and thirty CBCT three-dimensional volumetric renderings.

Seven dental faculty members at University of California at San Francisco participated in the study. These judges included four orthodontic and three oral and maxillofacial surgical faculty members. They were further stratified into four junior (less than ten years of clinical experience) and three senior faculty members (more than 10 years of clinical experience).

Every impacted maxillary cuspid was evaluated in single evening. Before starting, each judge reviewed the questionnaire as part of the calibration process. At each station, the clinician was asked to complete the questionnaire for every case. Each clinician was randomly assigned a start point. The time to complete all sixty questionnaires ranged from one and half to two and half hours.

After data collection StatView, Version 5 (SAS Institute Inc., Cary, NC) was utilized to evaluate differences between traditional radiographs and CBCT volumetric renderings, orthodontic and oral maxillofacial dental specialists, and clinical experience. Statistical analyses were performed accounting for the clustering within cases using SAS 8.1 (Cary, NC). Repeated measures tests were used to examine differences between traditional 2D and CBCT 3D images. Mean confidence and 95% confidence intervals were estimated. Paired t-tests compared confidence level differences. McNemar tests compared differences in dichotomous (i.e. yes/no) questions between 2D and 3D methods. Chi-square tests were used to compare questions between specialties (orthodontics versus oral and maxillofacial surgery) and between experience levels (junior versus senior). Cochran-Mantel-Haenszelchi-squares compared questions between specialties and between experience levels stratifying on case to control for case to case (tooth to tooth) variation. Intraclass correlations with random case effects were estimated to determine continuous measure reliability of the replicates overall and separately for 2D and 3D. Kappa statistics were used for categorical measures.

Intra-Rater Reliability

Intra-rater reliability for all questions was acceptable with a range from fair to perfect, depending upon the question (Table I and II). It appears that raters have more agreement with traditional radiographs compared to the CBCT images, but there was not a significant difference between the two modalities.

Table I. Intra-rater reliability, agreement, Kappa values.

Variable	*2D & 3D*	*2D*	*3D*
Mesial-Distal Location	0.76	0.92	0.61
Labial-Palatal Location	0.82	0.87	0.77
Vertical Location	0.63	0.73	0.53
Root Resorption	0.65	0.73	0.55
Orthodontic Treatment Plan	0.72	0.77	0.64
Orthodontic Treatment Plan (recover)	0.75	0.75	0.75
Orthodontic Treatment Plan (extract)	0.81	0.85	0.72
Number Of Recovery Vectors	0.54	0.53	0.54
Initial Recovery Vector	0.47	0.46	0.46
Second Recovery Vector	0.57	0.58	0.55
Anticipate Will Erupt Unassisted	0.78	1.0	0.59
Anticipate Additional Root Resorption	0.70	0.59	0.79
Request For Additional images	0.62	0.46	0.80
Surgical Access	0.63	0.61	0.61
Surgical Flap Design	0.73	0.78	0.69

Kappa Key:
(0.0-0.2) -poor
(0.2-0.4) -fair
(0.4-0.6) -moderate
(0.6-0.8) -substantial
(0.8-1.0) -perfect

Table II. Intra-rater reliability, Lin's Concordance.

Variable	*2D & 3D*	*2D*	*3D*
Confidence Of Diagnosis	0.55	0.60	0.50
Confidence Of Treatment Plan	0.41	0.41	0.43

RESULTS

Traditional Radiographs (2D) versus Cone Beam Computed Tomography Scans (3D)

Localization of Impacted Maxillary Cuspids

There were differences in the localization of the impacted cusp tip depending on the radiographic modality. There was 79% agreement among the judges on twenty-five teeth for the mesial-distal cusp tip position (one-sample chi-square test; Figure 8). The combined mode, 2D and 3D, had a range of agreement from 43% to 100% for each individual tooth (Figure 9). There was 84% agreement for the labial-palatal position (one-sample chi-square test; Figure 10). The overall mode had a range of agreement from 50% to 100% for each individual tooth (Figure 11). Fifty percent of the teeth had 100% agreement, and 76% had one or less clinician in disagreement (Figure 12). However, there were no statistically significant differences between 2D and 3D (Chi square test, $p<0.05$). There was 50% agreement when localizing the cusp in the vertical dimension.

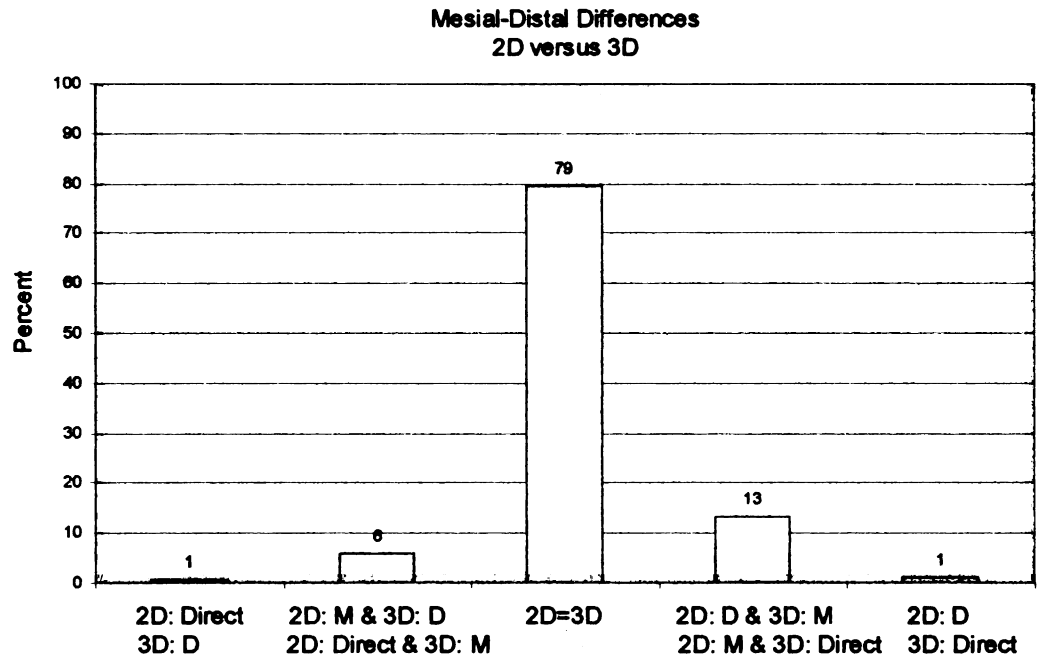

Figure 8. Mesial-Distal percent differences between 2D and 3D (M: mesial; D: distal). There was a high percentage of agreement (79%) between the traditional radiographs and the volumetric 3D views as to the localization of the impacted cusp tip. However, there was a 21% lack of congruence between the two modalities, with the various combinations illustrated above.

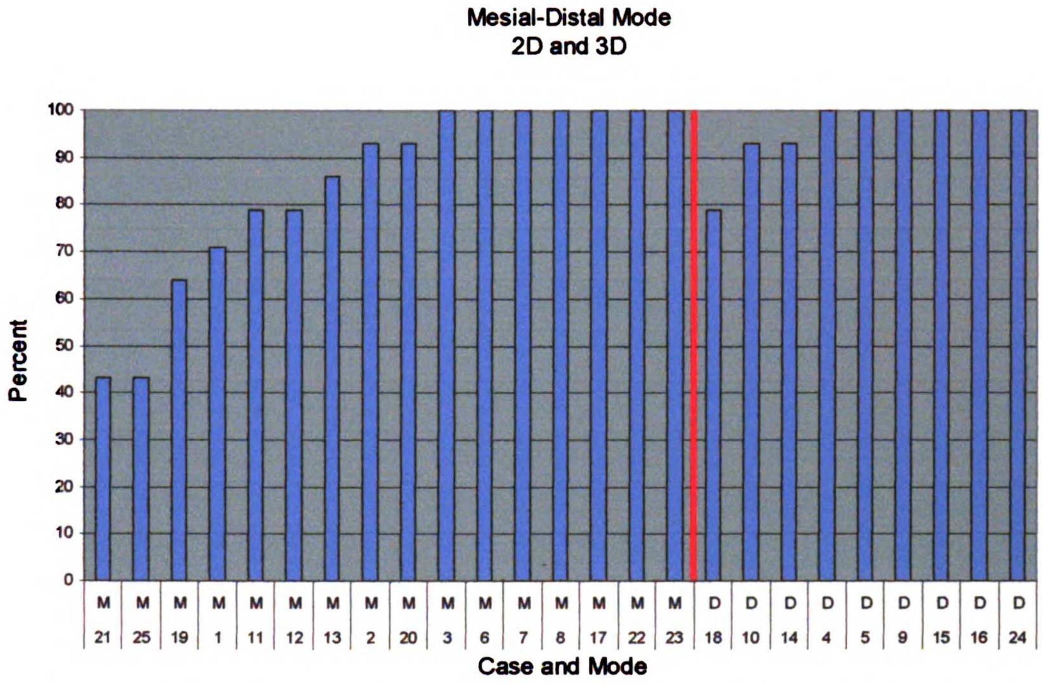

Figure 9. Mesial-Distal overall mode and percent agreement of 2D and 3D for each case and all seven judges (M: mesial; D: distal). This illustrates the percent agreement of the mode between the two modalities as to the mesial-distal position of each case, which had 100% agreement in over 50% of the cases.

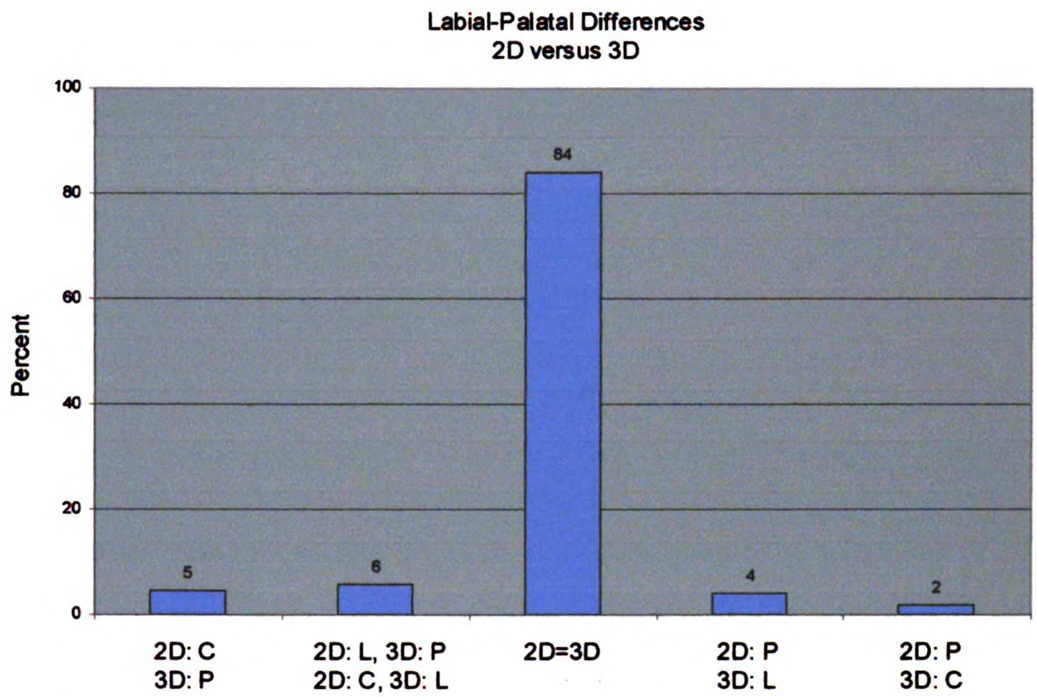

Figure 10. Labial-Palatal percent differences between 2D and 3D (L: labial; P: palatal; C: centered). There was a high percentage of agreement (84%) between the traditional radiographs and the Volumetric 3D views as to the labial-palatal localization of the impacted cusp tip. However, there was a 16% lack of congruence between the two modalities, with the various combinations illustrated above.

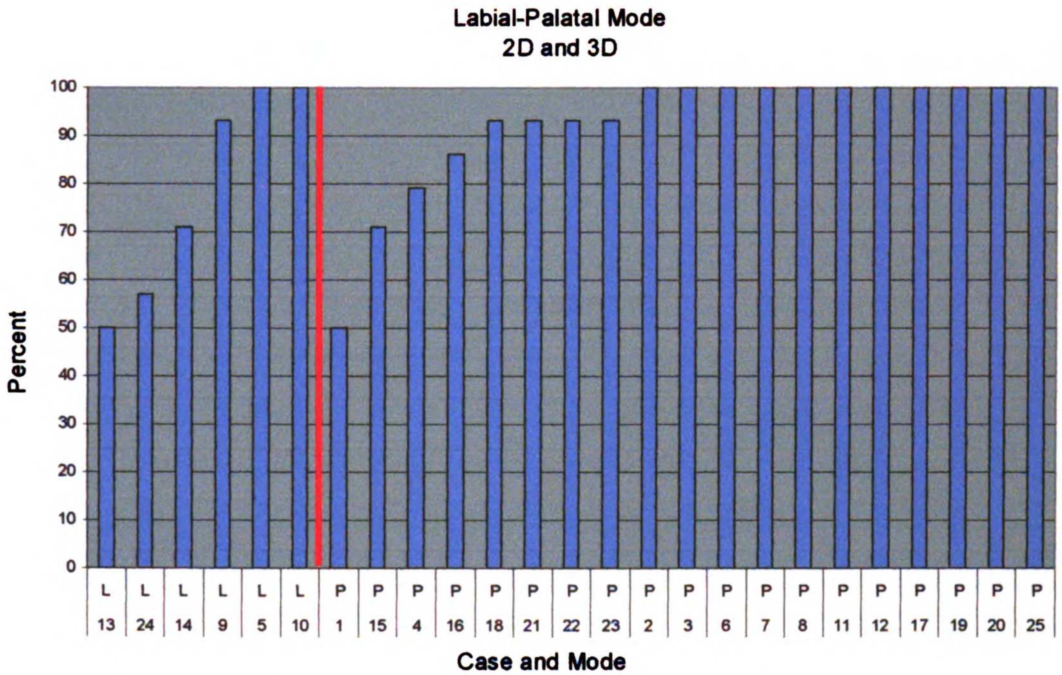

Figure 11. Labial-Palatal overall mode and percent agreement of 2D and 3D for each case and all seven judges (L: labial; P: palatal). This illustrates the percent agreement of the mode between the two modalities as to the labial-palatal position of each case, which had 100% agreement in over 50% of the cases.

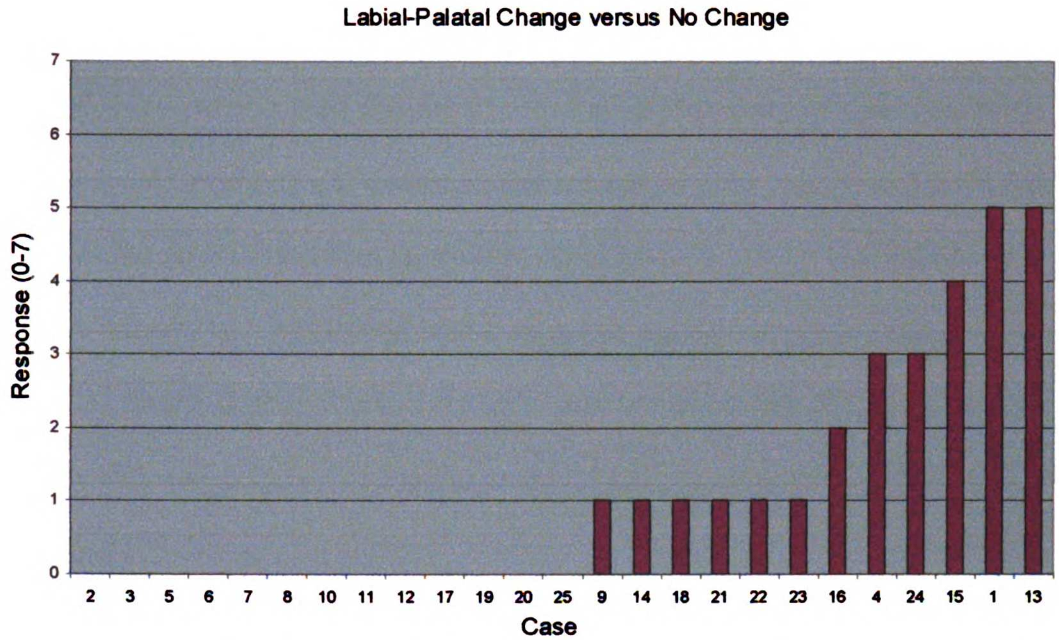

Figure 12. Labial-Palatal change or no change between 2D and 3D for each case with all seven judges. Differences between the two modalities is illustrated with the purple bars.

Root Resorption

There was a 64% amount of agreement in the diagnosis of root resorption (one-sample chi-square test; Figure 13). In the assessment of root resorption, the radiographic modality did influence the response (Chi square test, $p<0.0001$). The overall mode, the decision as to yes, no or unsure, for an individual tooth was never unanimous, but rather had a range of agreement from 36% to 86% (Figure 14). In 8% of the cases, the mode was unsure in the diagnosis of root resorption and was positive in the diagnosis of root resorption in only one case.

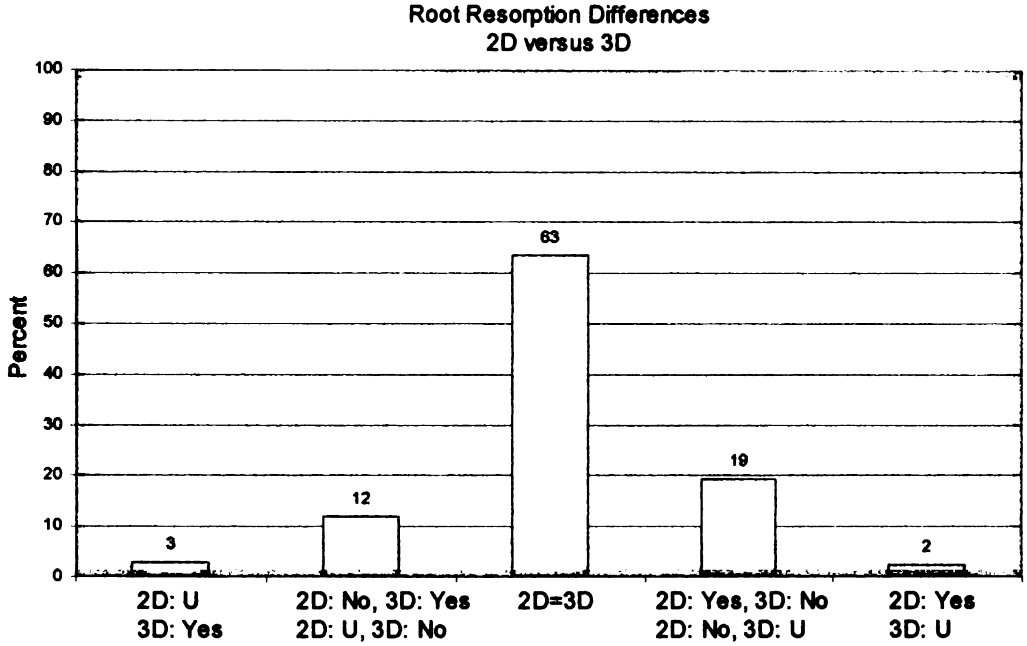

Figure 13. Root resorption percent differences between 2D and 3D (U: unsure). There was a moderate amount of agreement between the traditional radiographs and the volumetric 3D views as to the detection of root resorption on adjacent teeth. However, there was a 37% lack of congruence between the two modalities, with the various combinations illustrated above. Thus, root resorption had much more issues when comparing the two modalities, since there was only 63% agreement.

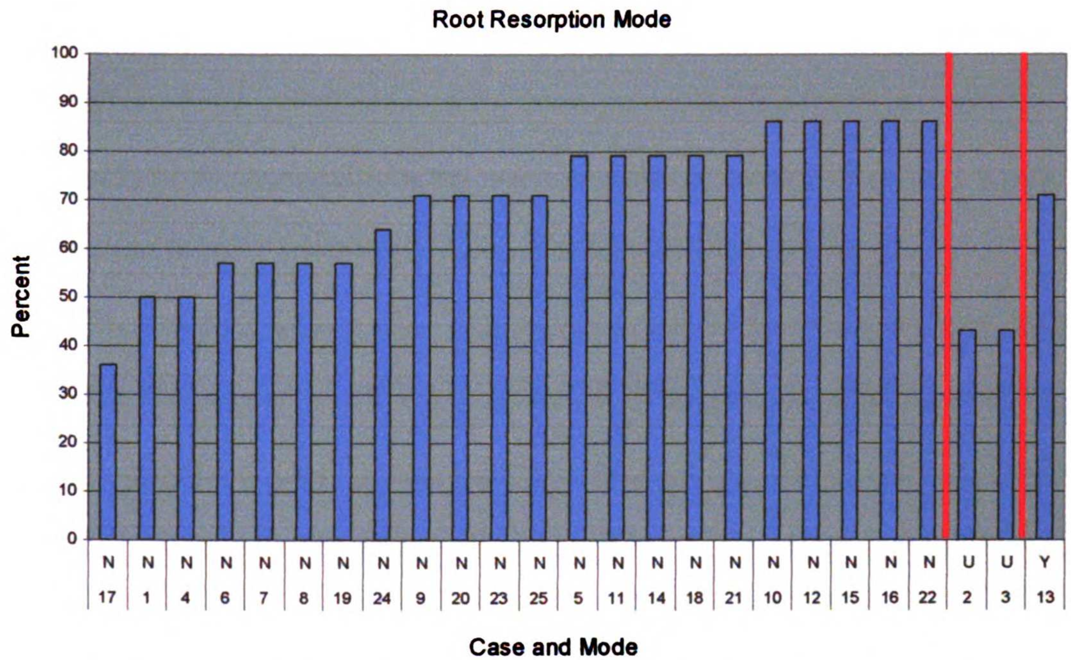

Figure 14. Root resorption overall mode and percent agreement of 2D and 3D for each case and all seven judges (Y: yes; N: no; U: unsure). This illustrates the percent agreement of the mode between the two modalities as to the labial-palatal position of each case, which was never above 90% agreement.

Orthodontic Treatment Plan

The derived orthodontic treatment plan was significantly influenced by the radiographic modality ($p<0.0001$). Fifty-three percent of the teeth-planned for extraction with traditional radiographs were treatment planned for recovery with cone beam computed tomography (CBCT) scans (McNemar test, chi-square=4.45, $p=0.035$; Figure 15). The overall mode for an individual tooth was unanimous in 24% of the cases with a range of agreement from 50% to 100% (Figure 16). When comparing the responses of 2D to 3D, there was complete agreement of the orthodontic treatment plan in 36% of the cases, and only one clinician was in disagreement was in another 18% of the cases (Figure 17).

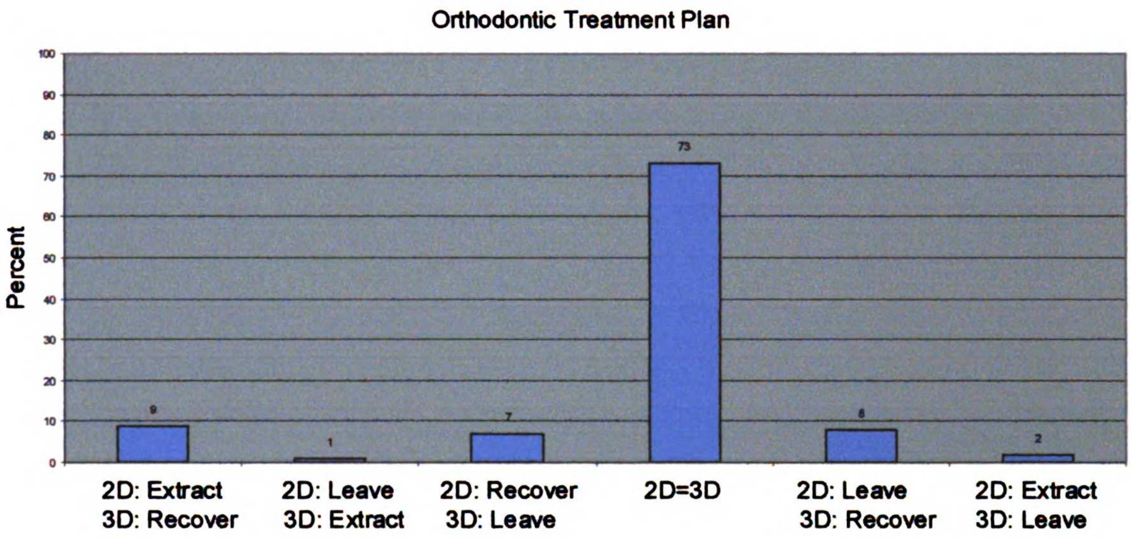

Figure 15. Orthodontic treatment plan percent differences between 2D and 3D. There was a strong amount of agreement between the traditional radiographs and the volumetric 3D views as to the orthodontic treatment plan (73%). However, there was a 27% lack of congruence between the two modalities, with the various combinations illustrated above.

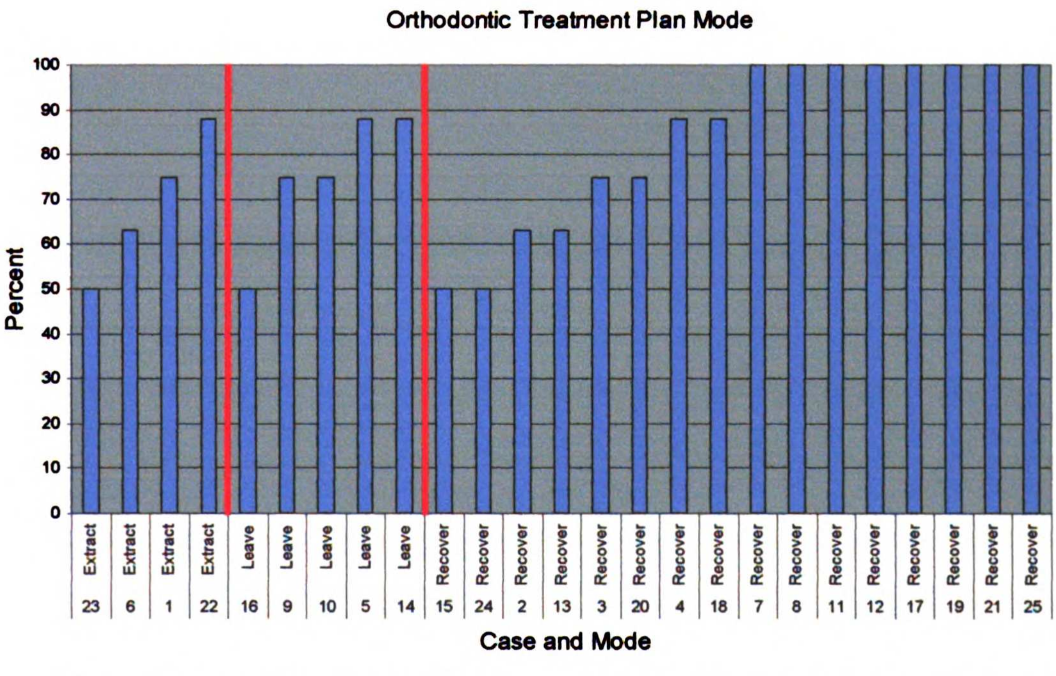

Figure 16. Orthodontic treatment plan shows overall mode (i.e. extract, recover, or leave) and percent agreement of 2D and 3D for each case and all seven judges. This illustrates the percent agreement of the mode between the two modalities as to the orthodontic treatment plan of each case, which had 100% agreement in 32% of the cases. When there was 100% agreement, recovery of the tooth was always planned.

Orthodontic Treatment Plan: Change versus No Change

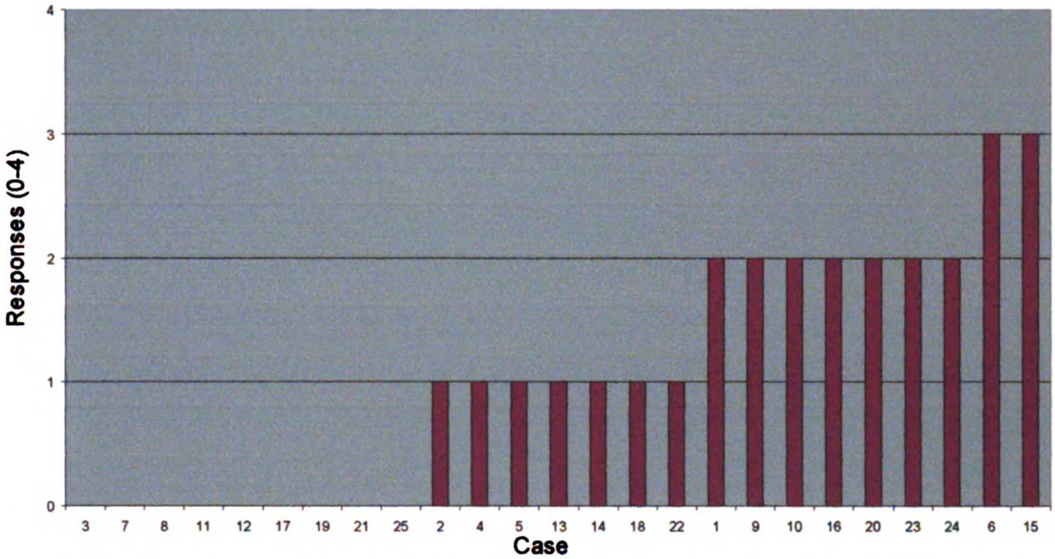

Figure 17. Orthodontic treatment plan change or no change between 2D and 3D for each case all seven judges. Differences between the two modalities is illustrated by the purple bars.

If a tooth was treatment planned to be recovered, then the selection of the initial recovery vector was significantly influenced by the radiographic modality ($p<0.0001$). Eleven of 12 teeth with an initial distal recovery vector with 2D images had a different initial recovery vector with 3D images. The overall mode of the initial recovery vector (i.e., distal, palatal, labial, extrusive, disto-palatal, or disto-extrusive) for an individual tooth was unanimous in 12% of the cases with a range of agreement from 20% to 100% (Figure 18).

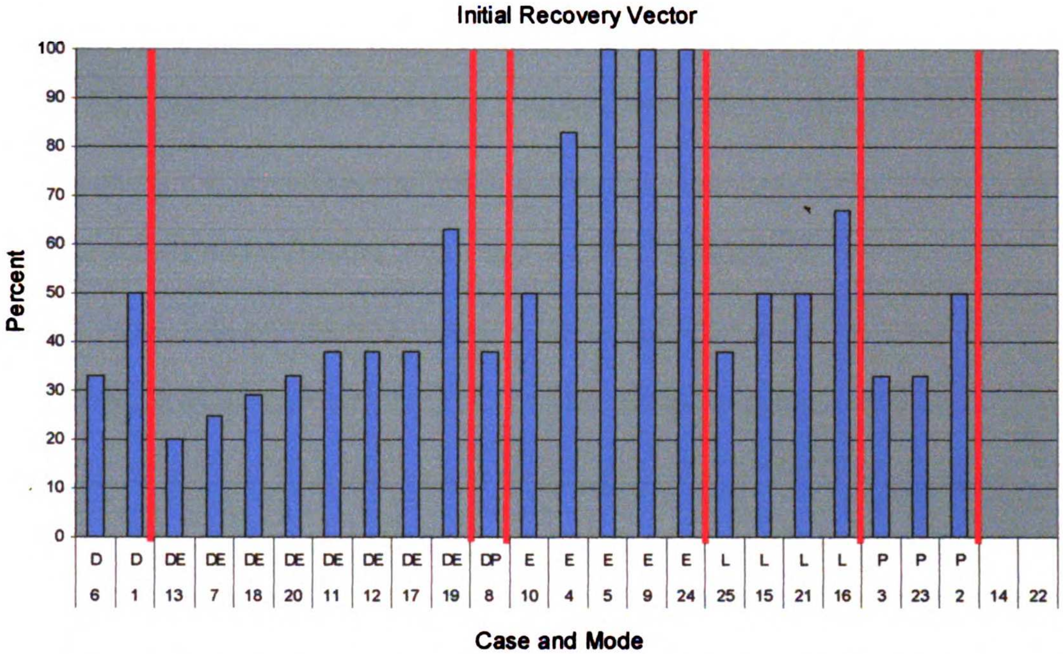

Figure 18. Initial recovery vector overall mode and percent agreement of 2D and 3D for each case and all seven judges (D: distal; P: palatal; L: Labial; E: extrusive; DP: disto-palatal; DE: disto-extrusive). This illustrates the percent agreement of the mode between the two modalities as to the initial recovery vector of each case, which had 100% agreement in 12% of the cases. When there was 100% agreement between the two modalities the initial recovery vector was extrusive.

There was a 42% lack of congruence for the second recovery vector. When predicting if the tooth would erupt unassisted, there was a 19% lack of congruence. In the prediction of additional root resorption, there was 21% lack of congruence.

Surgical Treatment Plan

The oral and maxillofacial surgeons' decisions of where to initiate surgical access for the impacted tooth had a 16% lack of congruence between 2D and 3D. When using traditional radiographs, the surgeons were unsure in 5% of the cases. They were never unsure when using CBCT images. There were 8 differences regarding palatal and buccal access with no significant trend or tendency related to radiographic modality. The overall mode of the two modalities to determine surgical access was unanimous in 68% of the cases (one-sample chi-square test; Figure 19). There were only 4 cases that had less than 70% agreement among the three surgeons.

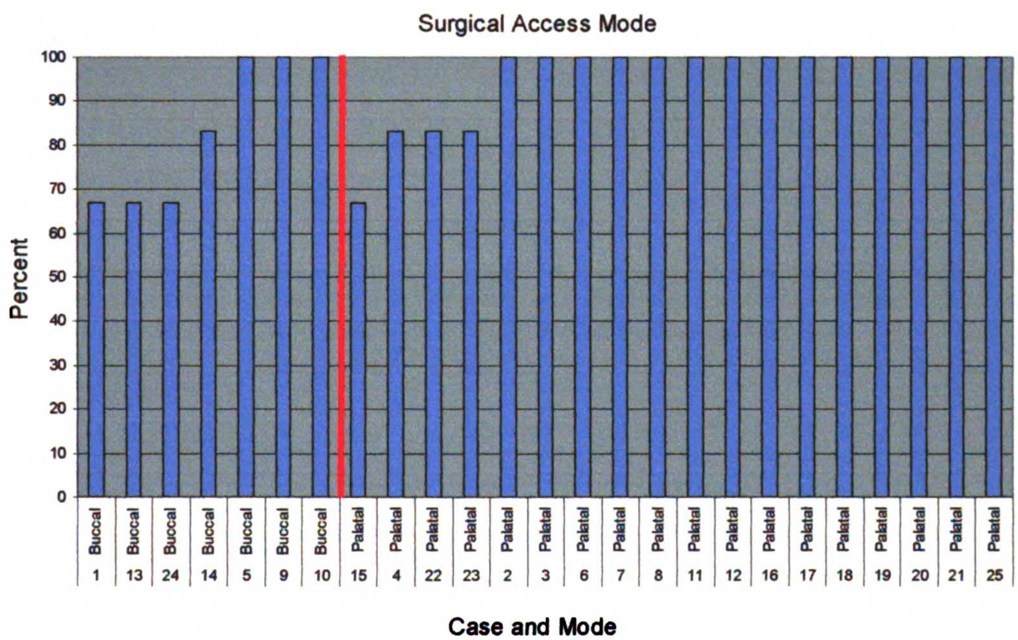

Figure 19. Surgical access overall mode and percent agreement of 2D and 3D for each case and all seven judges. This illustrates the percent agreement of the mode between the two modalities as to the desire for additional radiographs for each case. There was 100% agreement in 68% of the cases and the mode was usually palatal.

There was a 32% lack of congruence in flap design. The overall mode of the two modalities to determine the flap design was unanimous in only one case, with a range of agreement from 33%-100% (Figure 20).

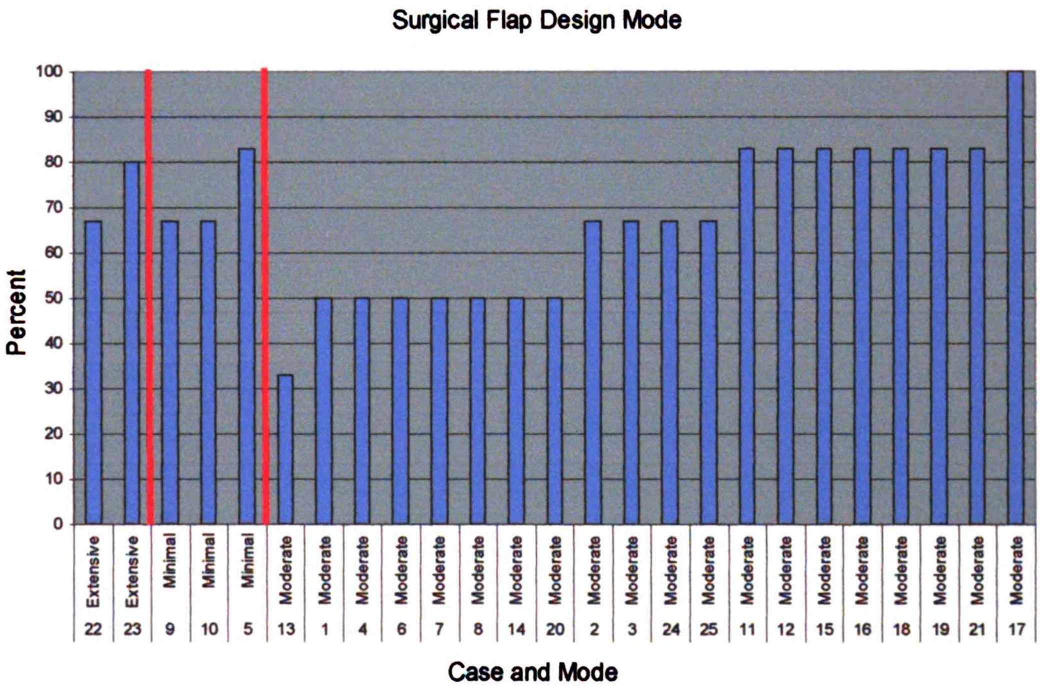

Figure 20. Surgical flap design overall mode and percent agreement between 2D and 3D for each case and all seven judges. This illustrates the percent agreement of the mode between the two modalities as to the desire for additional radiographs of each case, which had 100% agreement in only one case (tooth #17). The mode for surgical flap design was usually "moderate".

Additional Images

A request for additional images to obtain a more accurate diagnosis was more likely with traditional radiographs (McNemar's Test, $p=0.0016$). Sixty-one percent of the cases had no difference between 2D and 3D images (Figure 19). For 27% of the cases, additional images were requested with 2D but not 3D images. In contrast, 12% of the cases had requests for additional images

with 3D but not 2D. The overall mode for both modalities was always "additional images are not necessary". The mode was unanimous for only one case, with a range of agreement from 50% to 100% (Figure 20).

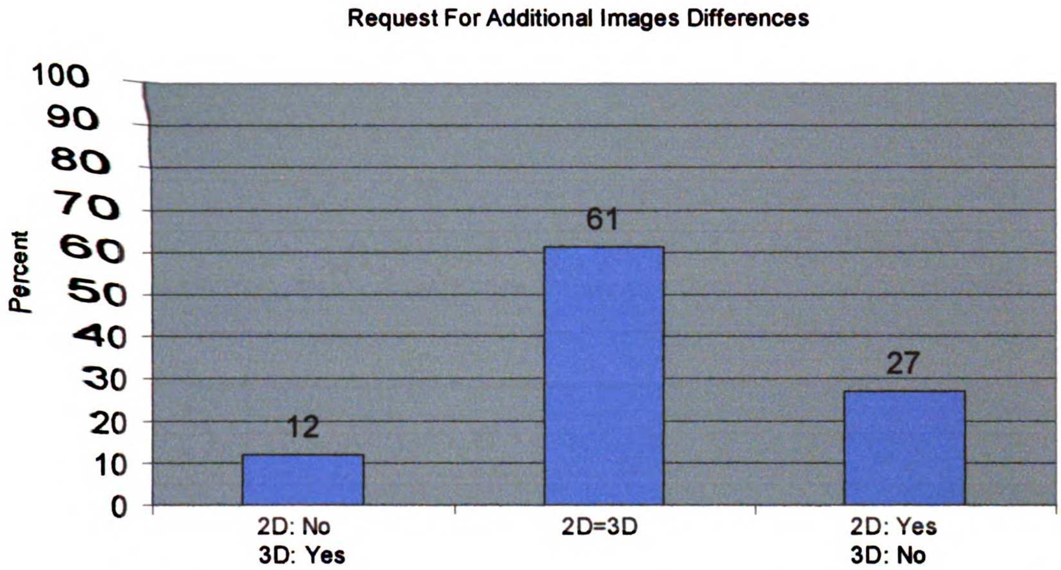

Figure 21. Request for additional images percent differences between 2D and 3D. There was a fair amount of agreement between the traditional radiographs and the volumetric 3D views as to the desire for additional images (61%). However, there was a 39% lack of congruence between the two modalities, with the various combinations illustrated above.

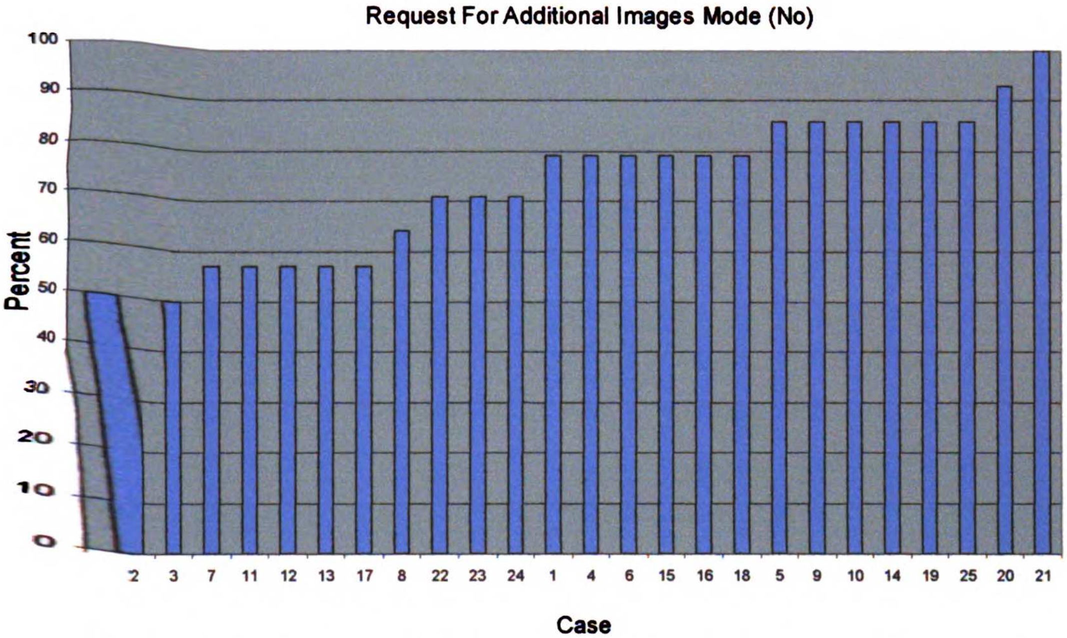

Figure 22. Request for additional images percent agreement between 2D and 3D for each case and all seven judges. For every case the mode was "no". This illustrates the percent agreement of the mode between the two modalities as to the desire for additional radiographs of each case, which had 100% agreement in only one case. The mode was always "no" for additional images.

Confidence of Diagnosis and Treatment Plan

The mean for the confidence of the diagnosis and treatment plan were each 8.6 for traditional radiographs (Figures 23 and 24).

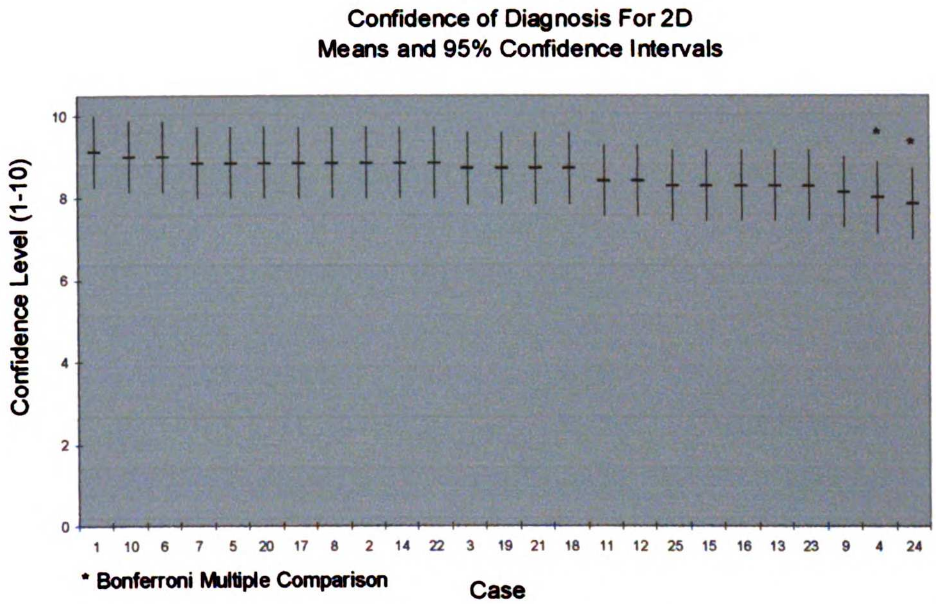

Figure 23. Self reported confidence of diagnosis using traditional images. Cases are ranked from highest confidence on the left to least confident on the right. The mean was 8.6 on a scale of 1-10.

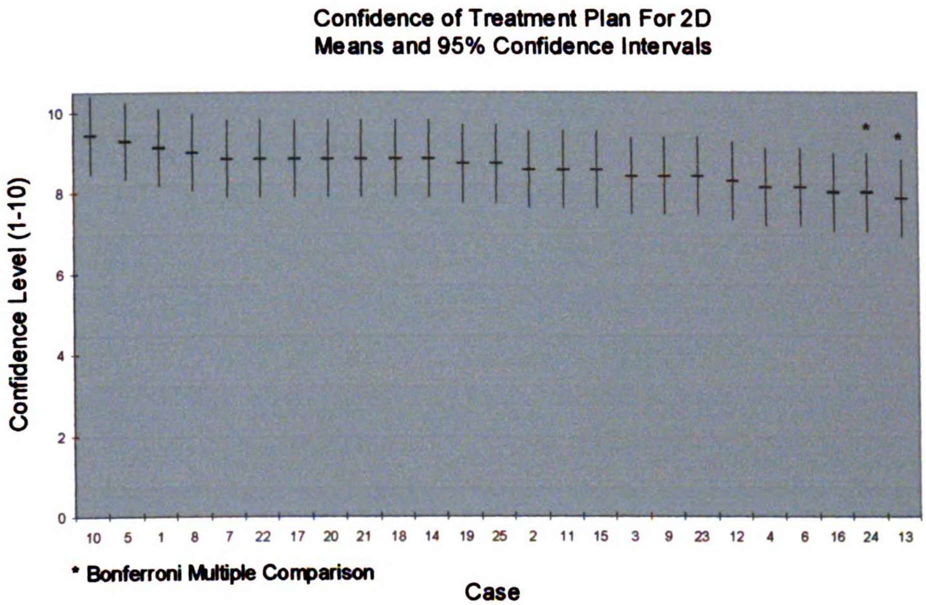

Figure 24. Self reported confidence of treatment plan using traditional images. Cases are ranked from highest confidence on the left to least confident on the right. The mean was 8.6 on a scale of 1-10.

For CBCT images, the means for the confidence of the diagnosis and treatment plan were 9.41 and 9.23, respectively (Figures 25 and 26). The mean difference in the confidence of the diagnosis was 0.8 with a standard deviation of 1.3. The mean difference in the confidence of the treatment plan was 0.6 with a standard deviation of 1.4, not significant.

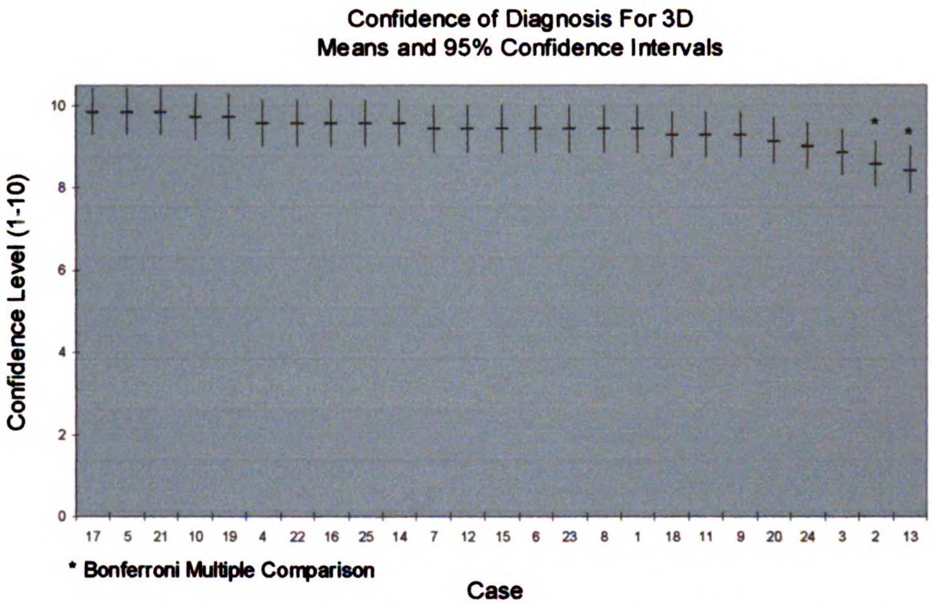

Figure 25. Self reported confidence of diagnosis using CBCT images. Cases are ranked from highest confidence on the left to least confident on the right. The mean was 9.4 on a scale of 1-10.

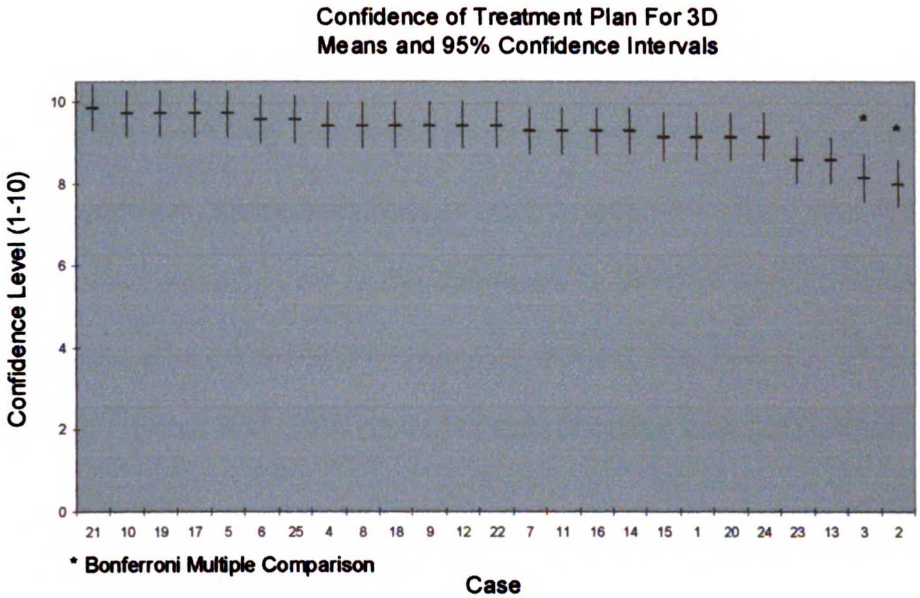

Figure 26. Self reported confidence of treatment plan using CBCT images. Cases are ranked from highest confidence on the left to least confident on the right. The mean was 9.2 on a scale of 1-10.

Junior Clinicians versus Senior Clinicians

Localization of Impacted Maxillary Cuspids

Clinical experience was found to be a significant factor when determining the vertical position of the cusp tip (Chi square test, p=0.031; Table III). Experience also played a role in the diagnosis of the root resorption using 2D and 3D images (Cochran-Mantel-Haenszel statistic p=0.006 and p<0.0001, respectively). There was 25% lack of congruence for junior clinicians and 52% for senior clinicians.

Root Resorption

Experience did influence the prediction if additional root resorption would occur with 2D & 3D images (Chi square test, p=0.003 and p=0.0066, respectively).

Orthodontic Treatment Plan

For those teeth in which treatment was planned for extraction or recovery there were no significant differences between junior and senior clinicians regardless of modality. Experience did influence the decision on how many recovery vectors were required for those cuspids treatment planned to be recovered using 2D and 3D images, (Chi square test p=0.0015 and p=0.0093, respectively). The selection of the initial recovery vector was also influenced by clinical experience when using 2D or 3D images, (p=0.0014 and p=0.015, respectively). For the initial recovery vector, there was 65% lack of congruence with senior clinicians and 75% for junior clinicians (Fisher Exact Test, p=0.0127).

There was no difference in the choice of the second recovery vector or prediction if the tooth would erupt unassisted.

Surgical Treatment Plan

For the oral and maxillofacial surgeons' decisions of where to initiate surgical access, experience was not a significant factor, but was a factor for the flap design for 2D and 3D images (Chi square test, $p=0.016$ and $p=0.007$, respectively).

Additional Images

The request for additional images to obtain a more accurate diagnosis was affected by experience with 3D images (Chi square test, $p<0.0001$) but not for 2D images. Senior clinicians never requested additional images when using 3D images.

Confidence of Diagnosis and Treatment Plan

There was no significant difference in the confidence of the diagnosis based on clinical experience.

Table III. Chi Square p-values comparing junior clinicians to senior clinicians.

Variable	Method	Chi Square, p-value
Mesial-Distal Location	2D	0.458
	3D	0.685
Labial-Palatal Location	2D	0.331
	3D	0.146
Vertical Location	2D	0.122
	3D	0.031
Root Resorption	2D	0.006
	3D	≤0.001
Orthodontic Treatment Plan	2D	0.710
	3D	0.070
Orthodontic Treatment Plan (extract)	2D	0.871
	3D	0.348
Orthodontic Treatment Plan (recover)	2D	0.111
	3D	0.008
Number Of Recovery Vectors	2D	0.001
	3D	0.009
Initial Recovery Vector	2D	0.001
	3D	0.015
Second Recovery Vector	2D	0.249
	3D	0.147
Anticipate Will Erupt Unassisted	2D	0.746
	3D	0.763
Anticipate Additional Root Resorption	2D	0.003
	3D	0.007
Request For Additional Images	2D	0.365
	3D	≤0.001
Surgical Access	2D	0.068
	3D	0.683
Surgical Flap Design	2D	0.016
	3D	0.007

Orthodontists versus Oral & Maxillofacial Surgeons

Root Resorption

Specialty training appeared to influence the diagnosis of root resorption when using either 2D or 3D images (Chi square test, $p<0.0001$ and 0.0002, respectively; Table IV). There was 45% lack of congruence between 2D and 3D images for orthodontists, and 26% for oral & maxillofacial surgeons, and where statistically evaluated controlling for each case with the Cochran-Mantel-Haenszel General Association Statistic and was statistically significant $p<0.0001$ for 2D and $p<0.0002$ for 3D.

Additional Images

Training also influenced the number of requests for additional images to obtain a more accurate diagnosis for 2D and 3D images (Chi square test, $p<0.0001$ and $p=0.007$, respectively).

Confidence of Diagnosis and Treatment Plan

The mean difference for the self reported confidence of diagnosis between 2D and 3D was 0.96 for orthodontists and 0.55 for oral maxillofacial surgeons (Table V). These mean differences were significantly different. There were no significant differences between orthodontists and oral & maxillofacial surgeons regardless of modality for the confidence of the treatment plan.

Table IV. Chi Square p-values comparing orthodontists and oral & maxillofacial surgeons.

Variable	*Method*	*Chi Square, p-value*
Mesial-Distal Location	2D	0.670
	3D	0.711
Labial-Palatal Location	2D	0.160
	3D	0.771
Vertical Location	2D	0.371
	3D	0.449
Root Resorption	2D	≤0.001
	3D	≤0.001
Request For Additional Images	2D	≤0.001
	3D	0.007

Table V. Self reported confidence assessment (1-10).

Variable	*Radiographic Modality*	*Orthodontist Mean*	*Oral Surgeon Mean*	*Significance p-value*
Diagnosis	2D	8.5	8.8	0.05
	3D	9.4	9.3	ns†
Treatment plan	2D	8.6	8.7	ns†
	3D	9.2	9.4	ns†

†ns: not a statistically significant difference

Tooth To Tooth Variation

The diagnosis of the labial-palatal position, and the derived orthodontic treatment plan, were influenced by tooth to tooth variation (Pearson Chi-square test $p<0.0001$). Individual tooth to tooth variations also influenced the self-reported confidence of the diagnosis and treatment plan when using CBCT images (Bonferroni Dunn t test, $p=0.050$ and $p=0.0003$, respectively). However, for the traditional radiographs, tooth to tooth variation did not significantly influence the confidence of the clinician regardless of experience and specialty training. Tooth complexity is suggestive of significance in relation to 3D confidence of diagnosis (ANOVA, $p=0.052$) while confidence of treatment plan is significantly related (ANOVA, $p=0.003$). This implies that confidence assessment is related to tooth to tooth variation.

DISCUSSION

This is the first study to evaluate the clinical implications of using cone beam computed tomography (CBCT) images for the diagnosis and treatment planning of maxillary impacted cuspids compared to traditional radiographs. In comparing the new volumetric three dimensional method of CBCT and traditional two dimensional radiographs, there is much agreement on how orthodontists and oral maxillofacial surgeons diagnose and plan treatment of a maxillary impacted cuspids. There were differences in what each method offered related to specific cases. Differences existed for some critical questions such as the labial-palatal position of the cusp tip, orthodontic treatment plan, and surgical treatment plan. One significant finding was that orthodontists were more likely to recover an impacted maxillary cuspid when using CBCT images. This is probably due to the fact that the clinician is more confident of the cuspid position, and their ability to successfully recover the tooth while minimizing risks to adjacent teeth. Another interesting finding was the 84% agreement among clinicians in the labial-palatal localization, which was also the identical level of agreement found with oral and maxillofacial surgeons when determining where to initiate surgical access. This implies that these two questions are directly related. The labial-palatal position is the most critical question for the surgeon if the tooth is to be removed or recovered. One could argue that since, fewer images were requested, and the self reported confidence was significantly higher with CBCT images, then this modality is superior. The surgeon is less likely to incorrectly access an impacted tooth, and the orthodontist is more likely to safely recover more impacted maxillary teeth.

Clinical experience, surprisingly, was not a significant factor in the selection of an orthodontic treatment plan regardless of modality. One may have expected a difference to exist between the junior and senior clinicians with the use of traditional radiographs, where a senior clinician would have significantly more experience. In addition, one may expect clinical experience would be offset through the use of CBCT images, where diagnosis and treatment planning is more explicit.

Specialty training, as expected, was a significant factor in the request for additional images and the diagnosis of root resorption. It is clear why an orthodontist is more discerning when determining the condition of adjacent teeth. The status of adjacent teeth is critical to the overall orthodontic treatment plan, and, specifically, the fate of the impacted tooth. This is not true for an oral surgeon who will be recovering or removing an impacted tooth at the request of an orthodontist. In addition, oral and maxillofacial surgeons tend to be more confident and had a significantly smaller mean difference between the two modalities of 2D and 3D images, compared to orthodontists.

Individual tooth variations did affect the labial-palatal localization of the impacted cuspid. As expected, most impacted teeth can be localized accurately with traditional radiographs. However, this is not the case for every impacted cuspid, where a tooth can be incorrectly localized, accessed surgically, and recovered using deleterious vectors. This finding is in agreement with previous research (Ericcson & Kurol, 1986). They demonstrated that 8% of impacted maxillary cuspids can not be accurately localized in the labial-palatal dimension with periapical radiographs.

Admittedly, this study did not address the accuracy of the either radiographic modality, rather only sought to determine if there were diagnostic and clinical implications. The limiting factor of this study was in not having a gold standard was the limiting factor in the determination of accuracy. Anatomical dissection would be necessary to assess accuracy of either modality, which is not probable since not all teeth were to be surgically accessed nor complete bone removal surrounding the impacted anatomical crown to make an accurate assessment.

The maxillary dentition was segmented by a single investigator from which radiographic views were developed and printed. Inherent problems include the accuracy of segmentation of the impacted cuspid and the selection of angles and views to be presented. In addition, the maximum benefit of CBCT images was limited since two dimensional prints were used, and the clinician was not able to manipulate the images to enhance diagnostic decisions.

Future studies should address and compare the accuracy of the radiographic modalities to a gold standard of the actual anatomical location of the tooth. Clinicians should also be allowed to access and manipulate the CBCT data to evaluate the true capability of this technology.

CONCLUSION

These results suggest that the use of two-dimensional and three-dimensional images of impacted maxillary cuspids can produce different diagnoses and treatment plans. Specifically, orthodontists are more likely to recover an impacted maxillary cuspid when using CBCT images. Both orthodontists and oral and maxillofacial surgeons are more confident using CBCT data compared to traditional radiographs. Clinical experience did not affect the selection of orthodontic treatment plan. Orthodontists are more discerning in the assessment of root resorption compared to oral and maxillofacial surgeons. Individual tooth variations do affect the determination of the labial-palatal position of an impacted maxillary cuspid. Three dimensional volumetric imaging may provide information for the clinician to make an improved diagnosis and treatment plan, and ultimately, result in more successful treatment outcomes and improved care for the patient.

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Appendix A

<u>ORTHODONTISTS:</u> Cuspid Questionnaire

1. **Where is the maxillary cuspid tip (mesial-distal)?**
   a. Distal to the midline of the adjacent lateral incisor
   b. Mesial to the midline of the adjacent lateral incisor
   c. Directly on the midline of the lateral incisor

2. **Where is the maxillary cuspid tip (labial-palatal)?**
   a. Palatal to the central or lateral incisor roots
   b. Labial to the central or lateral incisor roots
   c. Centered, labial-palatal, above the central or lateral incisor roots

3. **Where is the maxillary cuspid tip (vertical)?**
   a. Above the incisor apices
   b. Apical third of the incisor roots
   c. Middle third of the incisor roots
   d. Cervical third of the incisor roots
   e. At the DEJ

4. **Has there been any root resorption of adjacent permanent teeth?**
   a. Yes
   b. No
   c. Can't tell

5. **What is your treatment plan based on the radiographs?**
   a. Recover cuspid (go to question #6)
   b. Leave cuspid as is (go to question #9)
   c. Expose and pack (go to question 10)
   d. Extract cuspid (go to question #10)

6. **If you plan to recover the cuspid you plan to use:**
   a. One recovery path vector
   b. Two recovery path vectors
   c. Three recovery path vectors
   d. Four or more recovery path vectors

7. **Your initial recovery vector for the cuspid tip will be:**
   a. Distal
   b. Mesial
   c. Palatal
   d. Labial
   e. Extrusive
   f. Disto-labial
   g. Disto-palatal
   h. Disto-extrusive

(Over)

8. Your second recovery vector for the cuspid tip will be:
   a. Distal
   b. Mesial
   c. Palatal
   d. Labial
   e. Extrusive

9. Do you anticipate the impacted cuspid will erupt unassisted?
   a. Yes
   b. No

10. Do you anticipate additional root resorption?
   a. Yes
   b. No

11. If yes in question #10 which tooth (teeth)? (1-32)__________________

12. Are there any other images you would like to obtain for a more accurate diagnosis?
   a. Yes (go to question #13)
   b. No (go to question #14)

13. If yes in question #12 which additional images?

____

14. How confident are you of your diagnosis and treatment plan on a scale of 1-10 (1 being least confident and 10 being most confident)?

a. (diagnosis)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
b. (treatment plan)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

Appendix B

<u>ORAL SURGEONS</u>: Cuspid Questionnaire

15. Where is the maxillary cuspid tip (mesial-distal)?
   a. Distal to the midline of the adjacent lateral incisor
   b. Mesial to the midline of the adjacent lateral incisor
   c. Directly on the midline of the lateral incisor

16. Where is the maxillary cuspid tip (labial-palatal)?
   a. Palatal to the central or lateral incisor roots
   b. Labial to the central or lateral incisor roots
   c. Centered, labial-palatal, above the central or lateral incisor roots

17. Where is the maxillary cuspid tip (vertical)?
   a. Above the incisor apices
   b. Apical third of the incisor roots
   c. Middle third of the incisor roots
   d. Cervical third of the incisor roots
   e. At the DEJ

18. Has there been any root resorption of the adjacent permanent teeth?
   a. Yes
   b. No
   c. Can't tell

19. Are there any other images you would like to obtain for a more accurate assessment or to help determine your approach for surgical exposure and bonding?
   a. Yes (go to question #6)
   b. No (go to question #7)

20. If yes in question #5, which additional images? ___________________

21. How confident are you of the position of the impacted cuspid and surgical approach to expose and bond on a scale of 1-10 (1 being least confident and 10 being most confident)?

a. (position)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
b. (surgical approach)	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**

22. What would be your surgical procedural steps? (please circle)

a. Access:	a. Palatal	b. Buccal	c. Unsure
b. Flap:	a. Minimal	b. Moderate	c. Extensive