A Comparison of Plane Film VS Cone Beam CT to Diagnose and Treatment Plan Impacted Canines

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INTRODUCTION

The occurrence and treatment of unerupted teeth has been reported in the literature for years. (1) The maxillary canine is second only to the third molar in frequency of impaction.(2,3) The prevalence of impacted maxillary canine is 1-3 % of the population. (3-7) However, Ferguson reports that the incidence in the orthodontic practice population may be much higher. (8)

There are many theories concerning the etiology of canine impaction. Becker proposed that anomalies in size or position of the maxillary lateral incisor may lead to canine impaction due to a lack of "guidance" that would normally be provided by the distal of the normal lateral incisor root.(9) Warford et al. (10) cited delayed deciduous root resorption, abnormal tooth bud eruption and abnormal eruption rate as possible factors affecting guidance. Bjerklin and Ericson (11) proposed that there may be general and local factors involved. Local factors could be one or a combination of inadequate arch length, tooth bud position, early or delayed loss of the deciduous canine, iatrogenic issues or tooth size discrepancies. Jacoby reported that, at least where palatally impacted canines are concerned, arch length does not appear to be a factor.(12) However, Bjerklin and Ericson found that 42% of the palatally impacted canines in their study required extraction.(11) Schindel et al.(13)and McConnell et al.(14) propose that transverse discrepancies may play a role in impaction of the maxillary canine. Peck et al. (15) propose a genetic explanation for the palatally impacted canine. They suggest that facial and palatal canine impactions are different phenomena. Facial displacement is related to arch length deficiency and palatal impaction is positional anomaly of genetic origin. Baccetti (16) reported a relationship between palatally impacted canines and aplasia of second premolars, small maxillary lateral size, infraocclusion of primary molars and enamel hypoplasia. He suggested that the relationship was of a common genetic origin.

Proper diagnosis and treatment planning is important in order to bring the involved canine into the arch efficiently while protecting adjacent teeth. Prognosis improves dramatically when intervention is initiated at an early age. (17) The risk of root resorption of the maxillary permanent lateral and even

central incisors has been reported extensively and is a key concern regarding impacted canines. (5,6,7,11,15,18,19)
Many authors have reported on different techniques to assess the position of the canine and to evaluate the potential for canines to become impacted using traditional diagnostic records.(5-7,10-13,18-22) Historically, positional assessment has involved a panoramic radiograph and often another radiograph which could be lateral cephalometric, postero-anterior cephalometric, occlusal or periapical.(2,8-10,12-14) Schindel and Duffy added models to the diagnostic criteria.(13)

According to Ericson and Kurol(19) the orthopantograph alone is not an accurate means of evaluating the position of the impacted canine or resorption of adjacent teeth. Even with other radiographs added to the analysis positional accuracy was not 100%. On the other hand Chaushu et al. (23) used a "canine-incisor index" to allow 100% accuracy in identifying labial vs. palatal impaction using a single panoramic radiograph.
Warford et al.(10) used panoramic radiographs to evaluate the angle of the canine as well as the canine position relative to the lateral incisor(24) to predict impaction. He found that the position of the canine relative to the lateral incisor was significantly predictive of impaction, while the angulation of the canine did not improve predictability.
Bjerklin and Ericson (11) suggest a progression of radiographs beginning 8-10 years of age. They begin with palpation and periapical and panoramic films to delineate possible problems. Those children with ectopic canines also have computerized tomography to accurately determine position and determine if root resorption has occurred.
Jacoby (12) reported that periapical and panoramic radiographs are helpful for determining position and angulation of the impacted canine, but they may lead to erroneous conclusions concerning adequate space for the canine. He warned that radiographs can encourage four types of error regarding space analysis: 1. Periapical and orthopantomographic films do not give information about the labio-lingual space available. An inclined canine may appear to overlap the roots of the premolars and/or the incisor roots. This can give an inaccurate impression of crowding. 2. The orthogonal periapical film can enlarge parts of the image relative to other parts depending on the position of the parts relative to each other horizontally. This can also create the appearance of crowding where none exists. 3. The eccentric periapical radiograph taken of a mesial or distally displaced canine will give the impression of crowding. 4. Orthopantomographs have a significant amount of distortion. Small differences in positioning on repeated films will create different proportions of the jaw on film. Often the roots

of maxillary teeth appear to converge and give the impression of crowding. In Bishara's review of impacted maxillary canines(18) he acknowledged that there are a number of different combinations of radiographic exposures to aid in the evaluation of the position of canines, but he felt the periapical is "uniquely reliable." Using the tube shift technique for two films of the same area with a change in horizontal angulation if the object moves in the same direction as the cone it is positioned lingual.

Ericson and Kurol (19) used two or three periapical films as well as a vertex axial projection with rays parallel to the roots to the central incisors. Additionally they took orthopantograms and lateral cephalograms if orthodontic treatment was to be considered. To evaluate resorption of roots polytomography was used.

Jacobs(20) reported on several "accurate methods of localizing the impacted canine." They included the parallax or image/tube shift, two radiographs taken at right angles to each other and stereoscopy. He found the image tube shift to be the most recommended. However this technique does not allow an evaluation of tooth contact and possible resorption. For this tomography was recommended. Stewart et al. used panoramic radiographs with linear and angular reference lines to assess the position of the involved canine.(21) Mason et al. cited a number of combinations of the parallax concept of positioning including: two periapical films taken at different horizontal angles, one maxillary anterior occlusal and one lateral occlusal, and one panoramic and one maxillary anterior occlusal film. They reported on a comparison of two methods of radiographic localization of impacted maxillary canines. They compared vertical parallax from a panoramic and maxillary anterior occlusal radiograph and a single panoramic radiograph. They found significant variation between the examiners in the prediction of the location of the impacted tooth. The vertical parallax method was more accurate than the magnification method. The percentage of accurate localizations was 76% for parallax and 66% for magnification. However, there was 90% accuracy for palatally positioned teeth.

Gavel and Dermaut (25) claim that by combining the information on the cephalometric and panoramic radiographs a three dimensional estimation of the position of the canine can be achieved, therefore, reducing radiation exposure compared to other methods of localization.

In recent years the Cone Beam Computed Tomography (CBCT) has been used as a substitute for the multiple orthodontic radiographs. With one exposure, the lateral cephalometric image, posteroanterior cephalometric image, panoramic

film, joint films and 3-D films can be produced. Additionally, these films do not have the magnification errors and distortion found with conventional plane films. Studies have shown that the CBCT produces "more precise" location of anatomic landmarks.(26) Berco et al.(27) and Moshiri et al.(28) found that the CBCT was more accurate for most linear measurements than lateral cephalometric radiographs.

CBCT has also been found to uncover incidental findings in a significant number of patients. Cha, Mah and Sinclair (29) found that of 500 patients who had CBCT investigations 123 patients had incidental findings. Of 252 orthodontic records 54 records revealed incidental findings (21.4%)

How does CBCT compare with traditional methods of evaluating canine impaction? Walker et al. found that 3-dimensional volumetric imaging revealed a significant amount of information including: "the presence or absence of the canine, size of the follicle, inclination of the long axis of the tooth, relative buccal and palatal positions, amount of bone covering the tooth, 3D proximity and resorption for roots of adjacent teeth, condition of adjacent teeth local anatomic considerations, and overall stage of dental development."(30) Peck et al. (31) compared CBCT with panoramic radiographs in angular measurements on a stint with radiopaque markers constructed on plaster study models of 5 patients. They concluded that the panoramic radiograph is a good screening tool "but does not provide reliable information related to root angulation, particularly in the canine and premolar region…). Alqerban et al. found that CBCT was significantly better than panoramic radiographs for determining root resorption. (32) Bjerklin and Ericson found that adding 3D imaging to traditional diagnostic records and history changed the treatment plan in 35 of 80 patients. Of the patients with root resorption of adjacent teeth 53.8% had a change in treatment plan when information from 3D imaging was added to the diagnostic armamentarium. Of the patients with no discernable resorption on the original radiographs 34.1% had a change in treatment plan when information from 3D imaging was added to the diagnostic data. Without the additional information provided by the CT radiographs 6 of the 39 patients would have undergone extractions of more 9 lateral incisors than was ordered using the CT. Additionally, nine patients with non extraction treatment plans without the CT were changed to extraction when information from the CT was added. Two patients had the canine extracted instead of premolars because of the added information afforded by CT. Of the fourteen patients with no signs of resorption, eight patients treatment was changed from extraction to non extraction. Fifty percent more incisors with resorbed roots were noted using CT.(11)

One potential drawback to CBCT is the radiation dose. Studies have been done to compare the radiation dose compared to plane film.(33,34) Hujoel et al. reported that the organ dose to orthodontic patients using CBCT could vary dramatically from significantly greater than the dose from plane films to less than plane film dose depending on the type of machine used.(33) Mah et al. reported that the NewTom 9000 machine produced an effective dose of 50.3 uSv which is comparable to traditional dental imaging.(34) Improvements are being made in speed and radiation dose as the technology develops.

The benefit of 3D rendering is that improved visualization can be performed allowing the clinician to see clearly a three dimensional picture of the teeth and evaluate adjacent structures that may complicate treatment and make plans for proper treatment. Where impacted maxillary canines are concerned this information may make the proper diagnosis and treatment planning more predictable. The purpose of this paper is to compare the diagnosis and treatment planning to expose maxillary canines using traditional plane films vs. CBCT with 3D capability. The null hypothesis is "There is no difference in diagnosis and treatment planning for impacted canines using CBCT when compared with plane film radiography."

MATERIALS AND METHODS

All patients included for this study came from an Oral and Maxillofacial Radiology office. The study sample was chosen based on being in the late mixed dentition or permanent dentition with at least one unerupted canine. The subjects consisted of 35 patients with an age range of 10 to 68.2 years. The mean age was 14.6 years with a standard deviation of 8.7 years. There were 11 males and 24 females. A total of 50 impacted canines were included in the study with 15 being bilateral

Radiographs were made with the i-CAT Cone Beam 3-D imaging system (Imaging Sciences International, Hatfield, PA). The images were made with settings of .3mm voxel size and a 10 second exposure. For the "traditional diagnostic data" Xoran software (Xoran Technologies, Inc, Ann Arbor, Michigan) was used to construct a panoramic, and two periapical radiographs using the tube shift method to simulate traditional diagnostic data collected for evaluation of impacted canines. Xoran software was also used to scan the 3D data in multiplane rendering to allow views from the sagittal, coronal and transverse perspective.

A questionnaire was developed to help assess the position and orientation of the canine as well as potential damage to adjacent teeth, best access to the tooth and initial movement required to bring the canine in. Twenty one questions were used in the questionnaire. An evaluation was made by the author first on the basis of the panoramic, and periapical films. Later, an assessment was made on the same patients using the 3-D cone beam computed tomography. The answers to the questionnaires were then evaluated to establish whether differences exist in the interpretation of the two radiographic methods.

Diagnostic Questions

Type of records: Traditional 3D Record number:_____

1

Is the canine long axis in reasonable alignment with path of eruption?

Y
N

2

How many millimeters is the crown tip from the eruption site?

< 10 mm
> 10 mm

3

Is the tooth orientation near horizontal?

Y
N

4

Can the canine be exposed without damage to permanent teeth?

Y
N

5

Can the canine be moved directly into the arch?

Y
N

6

Is more than one direction of movement required to bring the canine into proper position?

Y
N

7

Are adjacent teeth in the path of eruption?

Y
N

8

Is the canine in contact with adjacent teeth?

Y
N

9

Is there evidence of resorption?

Y
N

10

Is there a significant chance of damaging adjacent permanent teeth?

Y
N

11

Does it appear that adjacent permanent teeth may be lost?

Y
N

12

Do adjacent permanent teeth need to be extracted in order to bring the canine in?

Y
N

13

Is there a good prognosis for bringing the canine in?

Y
N

14

Do adjacent teeth need to move first?

Y
N

15

Is there a reasonable substitute for the canine?

Y
N

16

Where is the crown relative to where it should sit in the arch?

facial
over ridge
palatal

17

Where is the crown relative to where it should sit in the arch?

mesial
normal
distal

18

Where does the incision need to be made to allow for efficient movement?

facial
over ridge
palatal

19

Where is the initial direction of pull?

facial
inferior
lingual

20

Where is the initial direction of pull?

mesial
inferior
distal

21

Are incidental findings evident?

Y
N

Figure 1. Questionnaire used to evaluate impacted canine position, orientation, relationship to other teeth and how to expose and move the tooth.

RESULTS

Since the data were collected twice on each patient at different times the Paired T-Test was chosen to analyze the results. The measurement of interest is the difference between the average score of plane film radiography and the average score of CBCT. Using SAS 9.2, the average difference between scores of the two techniques is 1.24 with a p-value of 0.0006. The 95% confidence interval for the difference between the scores of the two techniques is (0.5617, 1.9183). This implies that there is a significant difference between the CBCT and the traditional technique and that CBCT performs 0.5617 to 1.9183 total score points better than the traditional method.

When looking for the difference between the two techniques using the questionnaire. McNemar's test for 2x2 classification tables and Bowker's test of symmetry for 3x3 classification tables. Each 2x2 classification table represents agreement/disagreement in "Y" or "N" responses using both techniques. Each 3x3 classification table represents agreements in responses (for example facial, inferior or lingual) using both techniques. Analysis was done using a 0.05 significance level. The question concerning exposure without damage to adjacent teeth could not be analyzed because the responses for the two treatments were in agreement. Questions regarding adjacent teeth in the path of eruption and contact of the canine with adjacent teeth also could not be analyzed, but the paired portion in the CBCT was much higher compared to the traditional method.

There was no significant difference between the two methods of evaluation regarding questions involving orientation, path of eruption relative to adjacent teeth, complexity of movement, chance of damage to teeth or loss of teeth, mesio-distal position of the canine, prognosis for exposure, and prognosis for bringing the canine in.

Significant differences were found regarding contact with adjacent teeth, resorption, extraction of adjacent teeth, canine substitution, distance to erupt, position of the crown facial to palatal and the initial direction of pull to bring the canine in. There was also a significant difference in incidental findings between the two techniques. Palatal positioning was in agreement between the two methods. However, there were significant differences in locating canines situated facial or over the arch.

Incidental findings included enlarged follicle, supernumerary teeth, apparent mucosal disease, malformed teeth, agenesis of teeth, hypoplasia, asymmetrical development, apparent infection and other ectopic teeth.

2 Periapicals, Panoramic

Figure 2. Responses to questions using the traditional, Panorex and tube shift periapical technique.

3D Images

Figure 3. Responses to questions using the 3D imaging.

DISCUSSION

In developing a treatment plan for patients with impacted canines it is important to evaluate whether root resorption is present on the lateral or central incisors. Computed tomography has been shown to be superior for evaluating the existence of resorption and degree of damage.(11,32) Additionally, accurate visualization of the impacted tooth aids decisions concerning extractions potential for damage to teeth, direction of guidance and how to expose the tooth in order to minimize trauma to tissue and damage to adjacent teeth.

Both methods of visualization gave similar information regarding mesio-distal and vertical assessment for positioning. Traditional records were also adequate for establishing whether the canine was palatally impacted. However, traditional radiographs were inadequate for revealing if the canine was over the ridge or

facial. In reality this inadequacy can often be overcome using other diagnostic protocols such as palpation for teeth that are not too high. It is probable that distinctions of position between facial and over the ridge have to do with positioning of adjacent teeth. Given that the lateral incisor sits "around the corner" from the canine, the tube shift method of localization may give the false impression that the canine is facial when in actuality it is in a normal position. The differences in the two evaluation methods in this study were significant when evaluating contact with adjacent teeth, resorption, whether teeth should be extracted, initial direction of traction, and incidental findings. While the prognostic evaluations were similar, differences in initial direction of movement of the canine and decisions regarding extractions can make a significant difference in damage to adjacent teeth and time involved to bring a tooth into the arch.

Incidental findings are an important addition to the diagnostic information provided by CT. In this study 3D provided 63% more incidental findings than plane film. In one case this involved a palatal supernumerary tooth undetected on plane film.

In cases with insufficient space requiring extractions, knowing the condition of the incisor roots is important before deciding which teeth to extract. Some clinicians feel that replacing the lateral incisor with a canine is often a good option. While this author feels that the canine should function whenever possible in the position it was intended, this information is important to share with the patient in an informed consent.
Accurate localization and distinguishing the difficulty of eruption is paramount when evaluating impacted canines. Kau et al. have developed an interesting method of assessing degree of difficulty for treatment of impacted canines based on 3D imaging. The technique establishes a measuring standard for where the crown and the root are positioned relative to ideal in all three planes of space. The further away from normal the larger the number assigned. The numbers assigned to each dimension are added to give the "KPG" index. The larger the "index" number the more difficult the impaction. This may be a significant aid to the practitioner in assessing difficulty and time required to in order to properly inform the patient and better judge time required. (36)

3D rendering is also of interest in visualizing the impacted canine. Several software companies including Dolphin Imaging (Chatsworth, CA) have been developing this imaging process for some time. By being able to adjust the translucency of the volume the impacted tooth can be brought into view relative

to its position in the volume. The volume can then be sectioned and manipulated to give the surgeon an accurate impression of the tooth position relative to other teeth and where it needs to move.
The issue of radiation exposure is readily being addressed as technology improves. Exposure times have been greatly reduced while detail has been greatly improved. Today some CBCT units are capable of giving accurate volume data with no more radiation than a full mouth series of radiographs.(29) With the additional available information afforded by CBCT, this modality should become an important adjunct for the diagnosis and treatment planning of impacted canines.

CONCLUSION

3D imaging gave significantly improved information regarding diagnosis and treatment planning of impacted canines compared to traditional plane film radiographs. 3D images gave better information regarding distance to move the canine, evidence of contact with adjacent teeth, evidence of resorption, need for extraction, possibility of substitution, where the canine is relative to where it should be, initial direction of movement labio-lingually, and incidental findings. Further studies should be undertaken with multiple evaluators to confirm the results found in this study.

Special thanks go to Dr. David Hatcher for providing records from his Oral and Maxillofacial Radiology practice, for this study; and Ms Manasi Sheth for technical help with the figures.

REFERENCES

- Vanarsdall RL, Conn H. Soft-tissue management of labilally positioned unerupted teeth. AJODO. 2004; 125:284-93.
- Dachi SF, Howell FV. A study of impacted teeth. Oral Surg Oral Med Oral Pathol 1961; 14: 1165-9.
- Moyers RE. Handbook of Orthodontics. 4th ed. Chicago: Year Book; 1988: 140,387.
- Thilander B, Jakobsson SO. Local factors in impaction of maxillary canines. Acta Odontol Scand 1968; 26; 145-68.
- Ericson S, Kurol J. Radiographic assessment of maxillary canine eruption in children with clinical signs of eruption disturbance. Eur J Orthod. 1986; 8:133-40.
- Bishara SE. Clinical management of impacted maxillary

canines. Semin Orthodon 1998; 4:87-98.

- Cooke J, Wang HL. Canine impactions: incidence and management. Int J Periodontic Restorative Dent 2006; 26: 483-91.
- Ferguson JW. Management of the unerupted maxillary canine. Br Dent J 1990; 169:11-7.
- Becker A, Smith P, Behar R. The incidence of anomalous maxillary incisors in relation to palatally-displaced cuspids. Angle Orthod 1981; 51: 24-9.
- Warford JH, Grandhi RK, Tira DE. Prediction of maxillary canine impaction using sectors and angular measurement. AJODO 2003; 124:651-5.
- Bjerklin K, Ericson, S. How a compurterized tomography examination changed the treatment plans of 80 children with retained and ectopically positioned maxillary canines. Angle Orthod. 2006; 76:43-51.
- Jacoby H. The etiology of maxillary canine impactions. AJO 1983; 84: 125-32.
- Schindel RH, Duffy SL. Maxillary transverse discrepancies and potentially impacted maxillary canines in mixed-dentition patients. Angle Orthod. 2007; 77: 430-5.
- McConnell TL, Hoffman DL, Forbes DP, Janzen EK, Weintraub NH. Maxillary canine impaction in patients with transverse maxillary deficiency. ASDC J Dent Child; 63:190-5.
- Peck S, Peck L, Kataja M. The palatally displaced canine as a dental anomaly of genetic origin. Angle Orthod 1994; 64(4): 249-56.
- Baccetti T. A controlled study of associated dental anomalies. Angle Orthod 1998; 68(3):267-74.
- Zhang J, Zhang WJ, Wang XX, Xu JG, Huang Y. Orthodontic traction of impacted maxillary canine: a comparison of different ages. Shanghai Kou Qiang Xue. 2006; 15:130-2.
- Bishara SE. Impacted maxillary canines: A review. AJODO 1992; 101:159-71.
- Ericson S, Kurol J. Radiographic examination of ectopically erupting maxillary canines. AJODO 1987; 91:483-92.
- Jacobs SG. Localiazation of the unerupted maxillary canine: How to and when to. AJODO 1999; 115:314-22.
- Stewart JA, Heo G, Golver KE, Williamson PC, Lam EWN, Major PW. Factors that relate to treatment duration for patients with palatally impacted maxillary canines. AJODO 2001; 119:216-25.
- Mason C, Papadakou P, Roberts GJ. The radiographic localization of impacted maxillary canines: a comparison of methods. Eur J

Orthod. 2001;23(1):25-34)

- Chaushu S, Chaushu G, Becker A. Reliability of a method for the localization of displaced maxillary canines using a single panoramic radiograph. Clin Orthodon Res 1999; 2: 194-9.
- Ericson S, Kurol J. Early treatment of palatally erupting maxillary canines by extraction of the primary canines. Eur J Orthod 1988; 10: 283-95.
- Gavel V, Dermaut L. The effects of changes in tooth position on unerupted canines on cephalograms. Eur J Orthod. 2003; 25: 49-56.
- Ludlow JB, Gubler M, Cevidanes L, Mol A. Precision of cephalometric landmark identification: Cone-beam computed tomography vs conventional cephalometric views. AJODO 2009; 136:312.e1-312.e10.
- Berco M, Rigali Jr PH, Miner RM, DeLuca S, Anderson NK, Will LA. Accuracy and reliability of linear cephalometric measurements from cone-beam computed tomography scans of a dry human skull. AJODO 2009; 136(1): 17.e1-17.e9
- Moshiri M, Scarfe WC, Hilgers ML, Scheetz JP, Siveira AM, Farmin AG. Accuracy of linear measurements form imaging plate and lateral cephalometric images derived from cone-bean computed tomography. AJODO 2007; 132(4): 550-60.
- Cha J, Mah J, Sinclair P. Incidental findings in the maxillofacial area with 3-dimensional cone-beam imaging. AJODO 2007; 132: 7-14.
- Walker L, Reyes E, Mah J. Three-dimensional localization of maxillary canines with cone-beam computed tomography. AJODO 2005; 128(4): 418-23.
- Peck JL, Sameshima GT, Miller A, Worth P, Hatcher DC. Mesiodistal root angulation using panoramic and cone beam ct. Angle Orthod 2007; 77(2): 206-13.
- Alqerban A, Jacobs R, Souza PC, Willems G. In-vitro comparison of 2 cone-beam computed tomography systems and panoramic imaging for detecting simulated canine impaction-induced external root resorption in maxillary lateral incisors. AJODO 2009; 136: 764.e1-764-e11.
- Hujoel P, Hollender L, Bolton A, Young JD, McGee M, Grosso A. Head-and-Neck organ doses from an episode of orthodontic care. AJODO 2008; 133:210-17.
- Mah JK, Danforth RA, Bumman A, Hatcher D. Radiation absorbed in maxillofacial imaging with a new dental computed tomography device. Oral Surg Oral Med Oral Pathol. 2003; 96:508-13.

• Kau CH, Pan P, Gallerano RL, English JD. A novel 3D classification system for canine impactions-the KPG index. Intl J Med Robotics Comput Assist Surg 2009; 5: 291-296.

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Max21

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Max22Rt

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Max22Lft

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NNPMPILY

Max24

Y<NYNYYY?NNNNNYYNPMPIDN

Max25

Y<NYNYYY?NNNNNYNYPMPIDN

Max26Rt

Y<NYNNNY?YYY?NYYYYFM

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Max26Lft

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Max27

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Max28 Rt

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Max28Lft

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Max35Rt

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Max37

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NYYNFNFIIY

Max38Rt

Y<NYYNYYNNNNNYYNFMFIDN

Max38Lft

Y<NYYNYYNNNNNYYNFMFIDN

Max43

Y<NYYNY?NYNNNYYY

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Max44Rt

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Max44Lft

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Max 48Rt

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Max48Lft

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Figure 2. Responses to questions using the traditional, Panorex and tube shift periapical technique.

3D Images

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Max4

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NYYNPMPLIN

Max5

Y<N?NYYYYYYYYYYYYNODFIIY

Max6 Rt

N<YYNYYYYNYYYYYNNFMFIDY

Max6Lft

N<YYNYYYYNYYY

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Max7Rt

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Max13

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Max14Rt

Y<NYYNYYYNNNNYYNPMPLIY

Max14Lft

Y<NYYNYYYNNNNYYNPMPLIY

Max15Rt

Y<NYNYYYYNYNYYNO

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Max15Lft

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Figure 3. Responses to questions using the 3D imaging.