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ORIGINAL ARTICLE

A novel 3D classification system for canine impactions – the KPG index

Chung How Kau*
Philip Pan
Ron L. Gallerano
Jeryl D. English

Department of Orthodontics, University of Texas Health Science Center, Houston, TX, USA

*Correspondence to:
Dr Chung How Kau, Associate Professor in Orthodontics and Director of the 3D Imaging Facility, Department of Orthodontics, University of Texas Health Science Center, Houston, TX 77030, USA.
E-mail: chung.h.kau@uth.tmc.edu

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Abstract

Background 3D cone beam imaging allows localization of impacted canines, using spatial relationships, with excellent tissue contrast. The aim of this project was to assess the degree of difficulty for the treatment of impacted canines, based on the 3D information provided by cone beam imaging.

Methods 3D cone beam images taken from subjects with impacted canines were obtained from a private practice and school setting.

Results A novel measuring scale was devised, based on three different viewpoints, in order to grade the difficulty of impaction and the potential efficacy of treatment. Depending on its anatomical location, the cusp tip and the root tip are each given a number 0–5 in three dimensions taken from a pretreatment image. The sum of the cusp tip and root tip scores in the three views dictated our anticipated difficulty of treatment.

Conclusions A novel method of analysing impactions using cone beam imaging was proposed. This method utilizes the entire three views of a CBCT image.

Keywords 3D imaging; cone beam; canines

Introduction

An impacted tooth is defined as one that fails to erupt at its appropriate site in the dental arch, within its normal period of growth (1). After third molars, maxillary canines are the most frequently impacted teeth, with a prevalence in the range 0.9–3.0%, depending on the population examined (2). Females seem to be more commonly affected than males, for reasons unknown. Traditional radiographs can be somewhat limited in the visualization of impacted teeth, due to problems involving superimposition.

Three-dimensional (3D) volumetric imaging systems allow localization of impacted canines, using spatial relationships, with excellent tissue contrast. Cone-beam computed tomography (CBCT) uses a cone-shaped X-ray to acquire maxillofacial images with higher spatial resolution and lower radiation dose than conventional CT. From the volumetric data, software from the manufacturer enables multiplanar and 3D reconstructions valuable for orthodontic assessment. These secondary reconstructions provide different viewpoints of interest, including coronal or frontal, sagittal, and axial or horizontal, that allow for evaluation of the impacted tooth and surrounding structures. The proximity of the impacted canine to incisors is shown to be significantly correlated with incisor resorption (2–4). Understanding the precise location and variation of orientation of the impacted canines can be of benefit

to oral surgeons and orthodontists in their treatment planning. The aim of this article was devise a method to aid clinicians to quickly estimate the difficulty of treatment involving impacted canines, without having to do multiple measurements of angles and distances, to relay the approximate treatment plan to the patient.

Materials and Methods

Imaging system

Cone beam images were obtained from a routine clinical setting at the 3D imaging facility at the University of Texas Health Science Center at Houston. The CBCT images were acquired by the Sirona Galileos System, which acquires its images with a scan time of 14 s and has a reported radiation dosage of only 29 Si. The field of view was made up of a sphere with a diameter of 16 cm. The voxel size was 0.15–0.30 mm and the greyscale 12 bit. The image reconstruction time was 3 min.

The CBCT images were viewed using a standard commercial platform, Galaxis, provided by the CBCT device. Within this application, all 3D views, sagittal, coronal and axial, were clearly visible. In addition, normal radiographic projections were possible.

Results

KPG index

In this study, a grid-like scale was devised of the three different views (x, y and z) in order to grade the difficulty of impaction and the potential efficacy of treatment. Depending on its anatomical location, the cusp tip and the root tip are each given a number on a 0–5 scale on the three separate images taken before treatment. The sum of both cusp tip and root tip scores in the three views would decide the anticipated difficulty of treatment, classified as easy, moderate, difficult, and nearly impossible.

The *x* axis of locating the canine

The first dimension in which to scale the difficulty of treatment for an impacted canine is the relationship of the canine cusp tip or root tip to the adjacent teeth. For this scale, we used a traditional panoramic X-ray view. Lindauer *et al*. (5) previously created a method for predicting the eventual impaction of the maxillary canine, using the location of the cusp tip and its relationship to the adjacent lateral incisor as follows:

- *Sector I*: this represents the area distal to the line tangential to the distal heights of contour of the lateral incisor crown and root.
- *Sector II*: mesial to sector I, but distal to the line bisecting the lateral incisor's long axis.
- *Sector III*: mesial to sector II, but distal to the mesial heights of contour of the lateral incisor crown and root.
- *Sector IV*: all areas mesial to sector III.

Lindauer's method reportedly identifies up to 78% of the canines that are destined to become impacted, all of which have cusp tips in sectors II, III and IV (5). Results from the study by Warford *et al*. (6) correspond to Lindauer's findings, with 82% of their canines found in sectors II, III and IV.

In this study, we numbered our areas in the x axis relative to the adjacent teeth as follows (Figure 1):

0. Canine cusp tip/root tip is in the proper erupted location; no treatment necessary in this dimension.
1. Cusp tip/root tip is within the width of the alveolus on either side of the vertical line bisecting the canine.
2. Cusp tip/root tip is in the area between the edge of the alveolus and a vertical line bisecting the adjacent

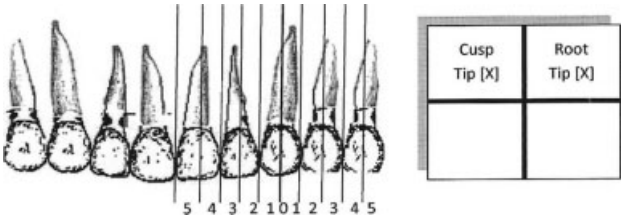

Figure 1. Anterior-posterior dimension (X) for both cusp tip and root tip; frontal view

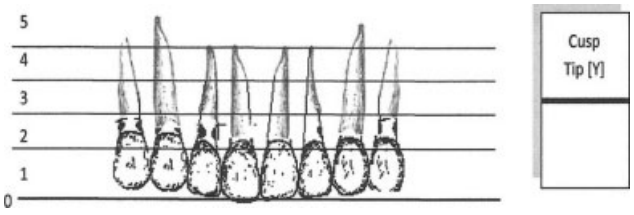

Figure 2. Vertical dimension (Y) for cusp tip; frontal view

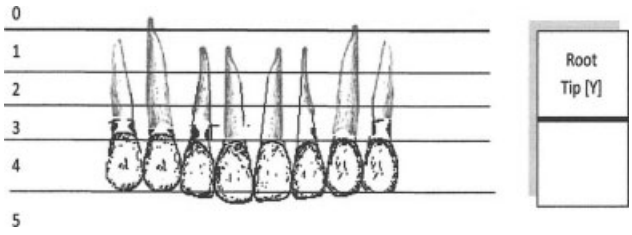

Figure 3. Vertical dimension (Y) for root tip; frontal view

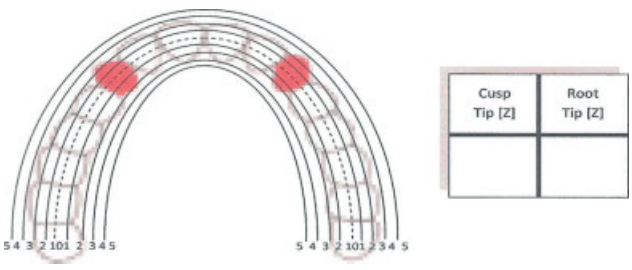

Figure 4. Deviation from the occlusal arch (Z); axial view

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tooth; either the distal half of the lateral incisor or the mesial half of the first premolar.
3. Cusp tip/root tip is in the further half of the neighbouring tooth; mesial half of lateral incisor or distal half of first premolar.
4. Cusp tip/root tip is in the distal half of the central incisor, or distal to the first premolar but mesial to the midline of the second premolar.
5. Cusp tip/root tip is in the mesial half of the central incisor or distal to the midline of the second premolar.

The cusp tip and the root tip are each graded separately, with the value of this dimension being designated in the X column. Areas 2 and 3 correspond to the cusp tip/root tip being located in the area of the lateral incisor or first premolar, the teeth immediately adjacent to the canine. Areas 4 and 5 correspond to the cusp tip/root tip being located in the area of the central incisor or the second premolar. The further away the tip is from its normal position, the higher the number. The areas that we have labelled 1–4 from the canine to the midline are similar to sectors I–IV previously used by Lindauer *et al*. to identify canine impactions. As a possible predictor of eventual treatment success, Ericson and Kurol (7) found that the more mesially located the crown, the more reduced the likelihood of eruption after deciduous extraction.

The *y* axis of locating the canine

Using the same panoramic view, the height of the cusp or root tip can be determined and scaled relative to its normal developmental position. The zones for the vertical dimension are similar to those used in the study by Liu *et al*. (2): coronal, cervical one-third of the root, middle one-third of the root, apical one-third of the root, and supra-apical. The scale for grading the canine cusp tip in the vertical dimension in the *y* axis is as follows (Fig 2):

0. Canine cusp tip is in the proper vertical location.
1. Cusp tip is in the coronal region.
2. Cusp tip lies in a horizontal plane with the cervical third of the incisor root.
3. Cusp tip lies in a horizontal plane with the middle third of the incisor root.
4. Cusp tip lies in a horizontal plane with the apical third of the incisor root.
5. Cusp tip is supraapical to the incisor root.

Since the root tip and the cusp tip are at opposite ends of the tooth, the scale for the location of the root tip is almost a direct opposite of the cusp tip (Fig 3):

0. Canine root tip is in the proper vertical location.
1. Root tip lies in a horizontal plane with the apical third of the incisor root.
2. Root tip lies in a horizontal plane with the middle third of the incisor root.
3. Root tip lies in a horizontal plane with the cervical third of the incisor root.
4. Root tip is in the coronal region.
5. Root tip is extends past the coronal region.

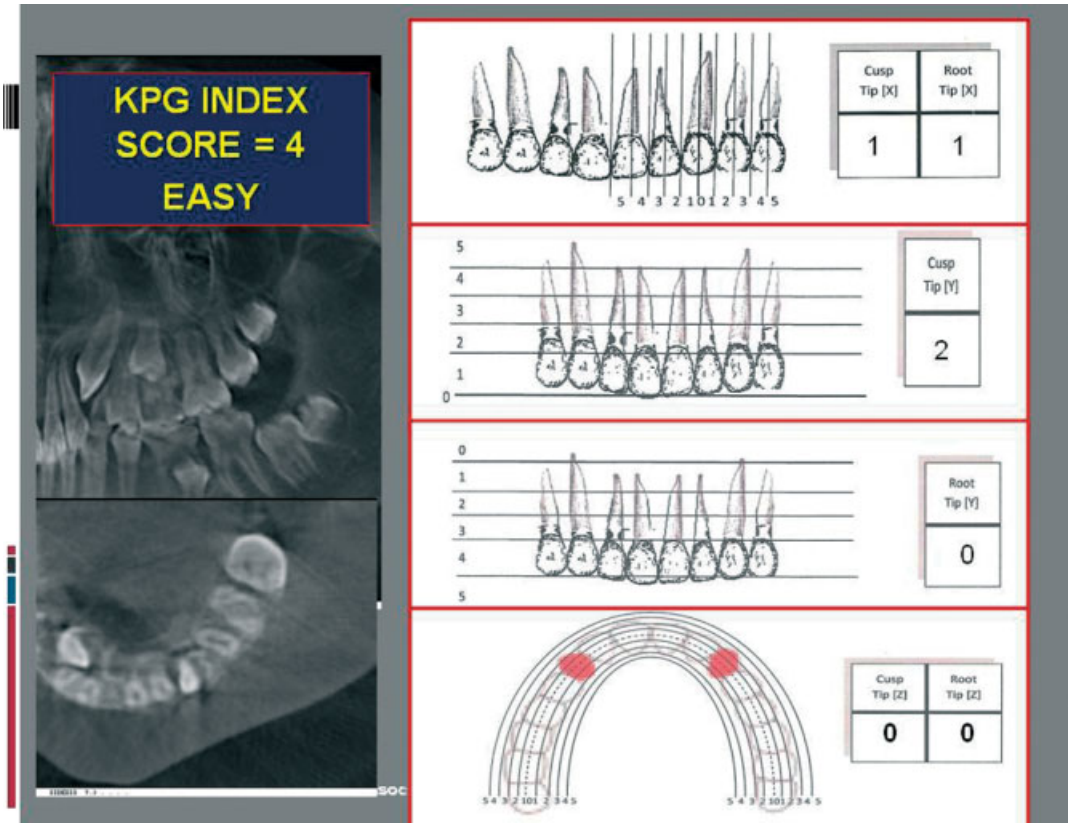

Figure 5. KPG index evaluation of an impacted canine determined to be easy to treat

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The *z* axis of locating the canine

Finally, the *z* axis for the canine was established. This was done using the axial views on the CBCT machine and makes the index unique, as this section is not normally seen with traditional radiographs. This scale uses distances measured perpendicularly in 2 mm increments from the cusp or root tip to the curved line of the occlusal arch. The divisions of the 0–5 scale are based solely on the distance of the impacted tip to the occlusal reference arch, different from the other two views, which are based more on anatomical location (Figure 4):

0. Canine cusp/root tip is in its proper location along the occlusal arch.
1. Cusp/root tip is 0–2.0 mm away from the occlusal arch of the cusp tip or root tip, either buccally or lingually.
2. Cusp/root tip is located in the area 2.0–4.0 mm away from the occlusal arch, either buccally or lingually.
3. Cusp/root tip is located in the area 4.0–6.0 mm away from the occlusal arch, either buccally or lingually.
4. Cusp/root tip is located in the area 6.0–8.0 mm away from the occlusal arch, either buccally or lingually.
5. Cusp/root tip is more than 8.0 mm away from the occlusal arch of the normal canine cusp or root tip, either buccally or lingually.

As the distance from the occlusal arch increases lingually, the cusp tip should also be located more mesially in the anterior–posterior dimension. Likewise, as the cusp tip is located more buccally, the cusp tip should also be found more distal to the normal position in the anterior–posterior dimension, due to the natural rounding of the occlusal reference arch.

Discussion

Assessment of difficulty

After scoring the cusp tip and root tip in the three views, the degree of difficulty of treatment is categorized as simple, moderately difficult and nearly impossible. These categories are determined by the sum of all scores for each individual tooth. Scores in the range 0–9 fall into the category of easy; 10–14 are moderate; 15–19 are difficult; and 20 and above are extremely difficult.

A simple impaction would result in a short time of treatment and maybe need basic orthodontic guidance. A moderate impaction requires longer treatment times, and an impacted canine scored as difficult would require even lengthier treatment, perhaps involving more advanced orthodontic techniques. An impaction that is classified as nearly impossible poses extreme difficulty for the orthodontist and could require the intervention of an oral surgeon before the canine can be brought into position, or the impacted tooth may simply need to be extracted.

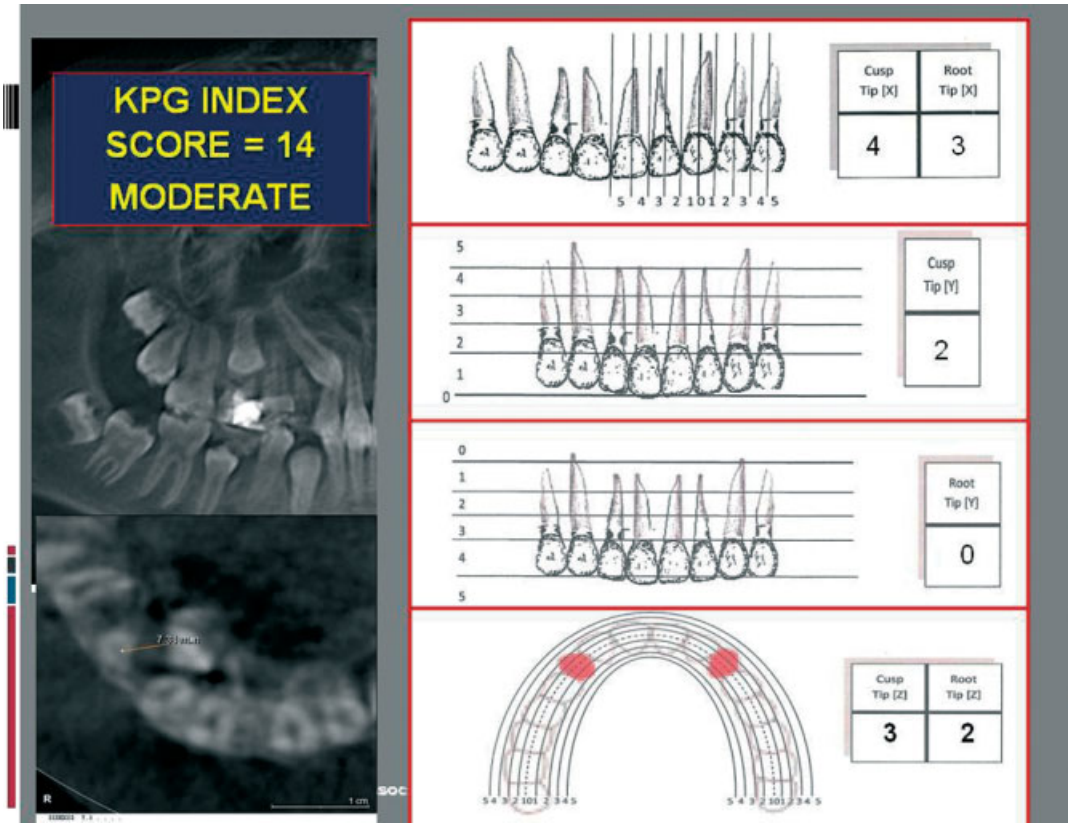

Figure 6. KPG index evaluation of an impacted canine determined to be moderately difficult to treat

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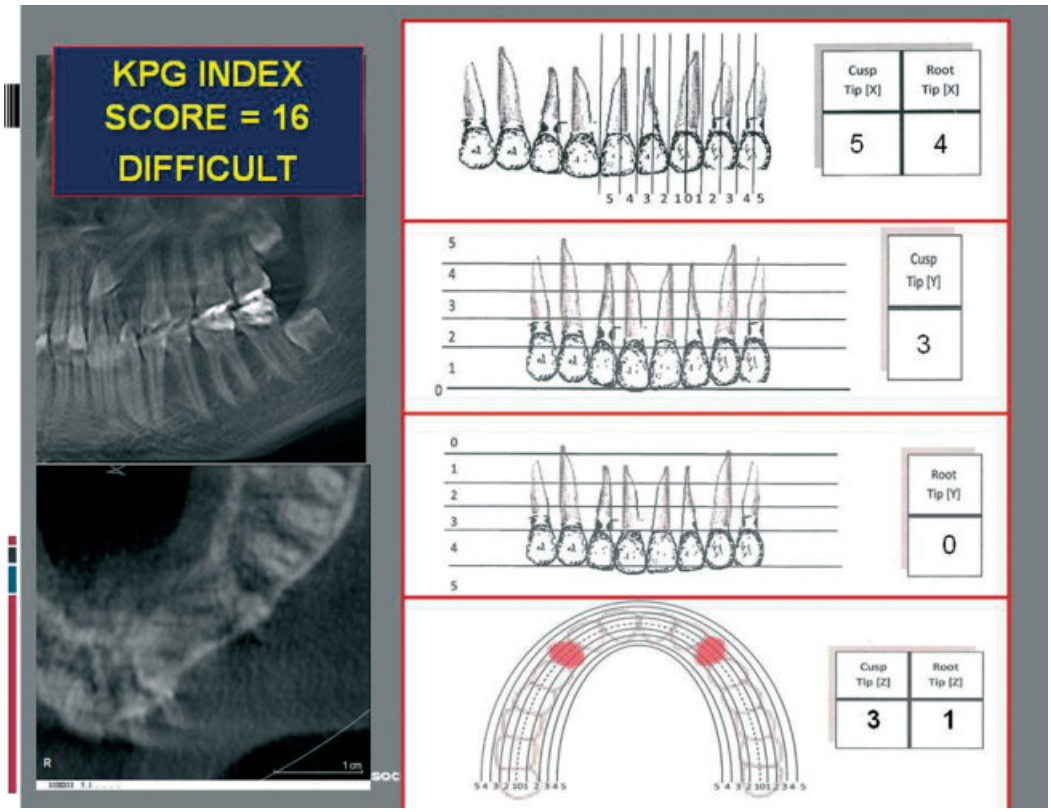

Figure 7. KPG index evaluation of an impacted canine determined to be difficult to treat

Case examples

The following four examples, shown in Figures 5–8, demonstrate the use of the KPG index. Whilst this system of classifying canines is still a work in progress; it is the first piece of work determining the use of 3D coordinates in the assignment of the degree of difficulty in canine impactions.

In theory, based on a 0–5 scale our maximum allowable score should be 30. However, in the vertical dimension, the root tip is normally rated a 0 because it originates high in the maxilla. In order to score a 5 in this dimension, the root tip would have to extend past the crowns of the adjacent teeth. This impossible situation prevents any impaction from scoring a 30. The unlikelihood of such a high score is the basis of our reasoning for dividing the moderate and difficult categories into only five points. There are, however, a few of our cases where the root tip was vertically lower than normal, laying the canine more nearly horizontal. These cases are all classified as difficult to treat. Other observations we note are that most of our impactions are palatal (31 canines, 73.8%) instead of labial, consistent with previous findings (3,8,9). The assignment of scores is based mainly on anatomical location. This allows other factors to either support or contrast with our classifications. For instance, occasionally the cusp tip or root tip may fall on the junction of two sections. It is then at the discretion of operator to decide whether it scores the higher or lower number. If the operator must choose between two similar areas in several of the scores, this could significantly alter the sum and potentially affect the outcome. The root tip itself may pose ambiguity when localizing its position. A considerable root deflection could alter the score, making it either easier or more difficult to treat. A cusp tip that is in close proximity to the roots of an adjacent tooth could also vary the realistic difficulty of treatment. The course of traction in this situation is not as straightforward as the numbers suggest, as the clinician must account for an effort to avoid damaging adjacent teeth. While our methodology may appear quite simple to the advanced orthodontist, we have undertaken a new way of analysing the degree of impaction of canines, using 3D cone-beam imaging. The utilization of the axial view offers more precise localization of the impacted tooth than a traditional panoramic radiograph. Orthodontists are able to more accurately estimate the length of treatment by this technology. Our future studies will involve a retrospective analysis of these 23 patients to determine whether the length of time it took to bring the canine into its proper position correlates with our preliminary classifications. Another form of validating our proposed scale is to survey orthodontists' thoughts on the degree of impaction for various cases. Then we would compare our pre-treatment classifications with their expert opinion. The earlier studies on the use of cone beam imaging to localize impacted canines has provided valuable applications to the field of orthodontics; our system is merely a manifestation of its clinical benefits.

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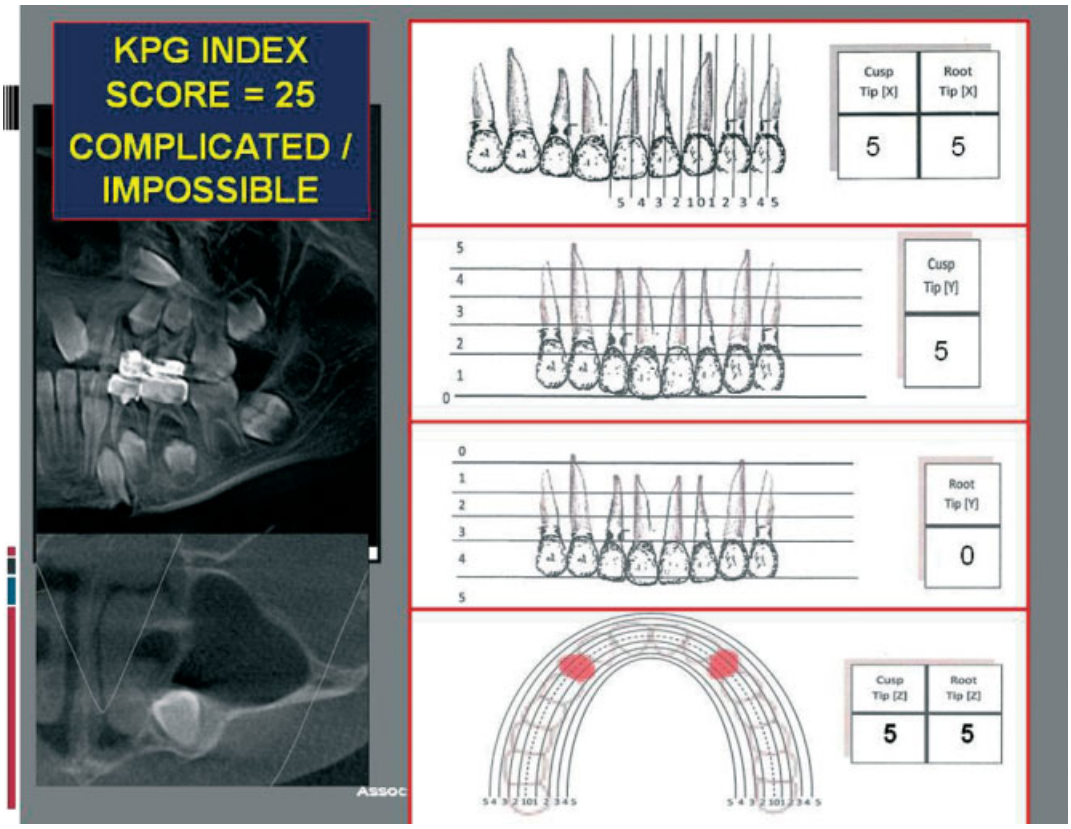

Figure 8. KPG index evaluation of an impacted canine determined to be complicated or near-impossible to treat

Conclusions

3D imaging has allowed a greater understanding of impactions with the dental arch and new methods for the classification should be devised. The KPG Index is a novel classification system that incorporates 3D information in CBCT imaging.

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