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Three-dimensional monitoring of root movement during orthodontic treatment

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Introduction: A significant objective of orthodontic treatment is to achieve proper and stable tooth positions that involve not only the crowns, but also their roots. However, the current methods of clinically monitoring root alignment are unreliable and inaccurate. Therefore, the purpose of this study was to develop a methodology that can accurately identify root position in a clinical situation. **Methods:** Pretreatment and posttreatment cone-beam computed tomography (CBCT) and extraoral laser scans of study models of a patient were obtained. Threshold segmentation of the CBCT scans was performed, resulting in 3-dimensional surface models. The pretreatment CBCT teeth were isolated from their respective arches for individual tooth manipulation. These isolated pretreatment CBCT teeth were superimposed onto the posttreatment surface scan depicting the expected root position setup. To validate the accuracy of the expected root position setup, it was compared with the true root position represented by the posttreatment CBCT scan. Color displacement maps were generated to measure any differences between the expected and true root positions. **Results:** Color map analysis through crown superimposition showed displacement differences of 0.148 ± 0.411 mm for the maxillary roots and 0.065 ± 0.364 mm for the mandibular roots. **Conclusions:** This methodology has been demonstrated to be an accurate and reliable approach to visualize the 3-dimensional positions of all teeth, including the roots, with no additional radiation applied. (Am J Orthod Dentofacial Orthop 2015;147:132-42)

The principal aims of orthodontic treatment are to maneuver teeth from malocclusion to an esthetic, functional, and stable occlusion with each whole tooth, crown and root included, positioned properly in 3 dimensions. To achieve this ideal occlusion, orthodontists often use Andrews' 6 keys as general guidelines.[1-4] Four of Andrews' keys (mesiodistal, faciolingual, and occlusal gingival positions, and axial rotation) are governed solely by the crowns of the teeth and are straightforward to monitor clinically. However, because crowns do not always accurately indicate the whole tooth angulation and inclination, the remaining keys (mesiodistal angulation and faciolingual inclination) are better judged by involving the roots.[5-8] Therefore, the ability to visualize the roots of the teeth would significantly help orthodontists to achieve all 6 keys.

The gold standard for monitoring and finalizing root position is to check panoramic x-rays at the initial, progress, and finishing stages of orthodontic treatment.[9,10] However, panoramic x-rays may be inaccurate in depicting the true root positions. Numerous studies have shown that panoramic radiographs contain distortions because of nonorthogonal x-ray beams directed at the target teeth.[11-14] Yet most orthodontists still use panoramic radiographs to visualize and correct root positions as shown in a 2008 survey, which found that 67.4% and 80.1% of American orthodontists take progress and posttreatment panoramic x-rays, respectively, because better alternatives are not readily available.[15] Therefore, the development of a new and accurate approach for visualizing the position and angulation of roots is necessary.

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Fig 1. Clinical photographs of orthodontic treatment from pretreatment to posttreatment.

Cone-beam computed tomography (CBCT) is a technique that has recently become more commonly used in orthodontics. Unlike panoramic radiographs, CBCT scans depict the true root positions and angulations in 3 dimensions. Furthermore, any distortions in the CBCT scans have been shown to be clinically insignificant.[11,16-19] However, clinicians often take progress and posttreatment records, which would require multiple CBCT scans. Multiple scans would expose the patient to higher levels of radiation; this is not recommended clinically, especially in children.[20-22]

Recently, a new methodology was reported that combines a single CBCT image with intraoral scans with the capability to track the root position at any stage of orthodontic treatment.[23] However, this approach was demonstrated only in an ex-vivo typodont model. The aim of this study was to translate this previously reported methodology from a bench-top typodont model to a patient to develop an accurate approach to monitor root positions clinically throughout orthodontic treatment with minimal radiation.

MATERIAL AND METHODS

We obtained records from the patient database of the Department of Orthodontics of Pontifical Catholic University of Rio Grande do Sul in Brazil. These records included pretreatment and posttreatment CBCT scans and laser scans of poured-up casts of 1 patient. These casts were poured with orthodontic stone from alginate impressions. The patient was a 12-year-old boy with a skeletal and dental Class II malocclusion treated by an author (A.W.) with the Haas-type rapid palatal expander followed by combined headgear therapy and