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A method for the geometric standardization of intraoral radiographs for long-term follow up of replanted teeth: a case report

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Abstract – The interpretation of the set of radiographs taken during the follow-up period after tooth replantation might pose several difficulties, especially the inability to adequately reproduce the projection geometry of the exposures. This article describes a method for the geometric standardization of intraoral radiographs using a custom-made apparatus comprising a film-holder attached to an occlusal splint for the long-term follow up of dentoalveolar trauma. The method was applied in a patient who suffered an avulsion of the maxillary central incisors and had the teeth replanted after 4 h in saline storage. Endodontic treatment started 7 days after the trauma with changes of a calcium hydroxide intracanal medication every 15 days in the first 2 months and thereafter at 30-day intervals for 8 months. Root canal filling was carried out after this period. The radiographic exposures taken at the follow-up visits were standardized to identify the possible alterations during the repair process, such as root resorptions. A maxillary arch impression was made with alginate, and the model was cast in stone for fabrication of an acetate occlusal splint. The custom-made apparatus used for standardization of the radiographic exposures was fabricated by fixing a Rinn X-C-P film-holder and a 5-mm-long piece of 0.7-mm orthodontic wire to the occlusal splint with autopolymerized acrylic resin. Radiographs were taken at 4-month intervals, starting 10 months after replantation up to 76 months. The images were digitized and analysed using the Digora system. The length of the central incisors was determined to verify the reproduction of the projection geometry of the exposures and the orthodontic wire served to assess accuracy during length estimations in the radiographs. The method described in this article for geometric standardization of intraoral radiographs provided a consistent reproduction of the geometric exposure parameters, being indicated for use in the radiographic follow up of cases of dentoalveolar trauma.

Key words: radiographic standardization; dentoalveolar trauma; tooth avulsion; tooth replantation

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Traumatized teeth should be monitored frequently during the first year post-trauma, and re-examination at yearly intervals should be carried out thereafter. Clinical and radiographic examinations provide essential information for planning of treatment and evaluation of the outcomes (1, 2). The preoperative assessment determines the severity and extension of the injury, outlines the treatment plan and establishes parameters to be reproduced in the follow up (3). The subsequent examinations are mandatory to identify symptomatic teeth with excessive mobility, loud metallic sound to percussion (indicating ankylosis), radiographic evidence of root resorptions, periapical radiolucent areas and presence of infection foci. Long-term clinical and radiographic follow up is therefore highly recommended for the cases of dentoalveolar trauma (2, 3).

Digital radiographic imaging techniques minimize the exposure of patients to radiation, reduce the image acquisition time and limit the environmental contamination, while at the same time providing high-resolution, high-quality images that may improve the diagnostic interpretation of radiographic findings in terms of reliability and accuracy (4). Digital radiography (5), conventional computed tomography (6), cone-beam computed tomography (7), magnetic resonance imaging (8), subtraction radiography (9) and computer-assisted analysing systems for processing and manipulation of non-standardized conventional radiographs (e.g. digital adjustment of brightness and contrast) (10, 11) are very useful resources for establishment of diagnosis and treatment plan in different areas of dentistry. However, the cost-effectiveness of the use of any auxiliary diagnostic resource should always be weighed as, apart from equipment costs, all these methods require the use of expensive proprietary imaging programs, which limit their applicability in daily clinical practice.

Conventional periapical radiography is an important complimentary diagnostic resource for the identification

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of pathological processes in the maxillomandibular region (12). However, an accurate diagnosis based on radiographic findings depends on having non-distorted high-quality images, especially considering that a major limitation of conventional radiographs is to provide two-dimensional information of a three-dimensional structure (13, 14). In addition, care should be taken because radiographs alone do not provide conclusive evidence at different moments in the postoperative follow up, being essential to have standardized images for comparative purposes.

As the superposition of structures or bone defects limits the diagnostic power of radiographs (15, 16), standardizing some parameters, such as radiographic film position, X-ray beam angulation and film-focus/film–object distance, with the use of a radiographic film-holder, is important to adequately reproduce the projection geometry of the exposures at different moments (17). There is a consensus in the literature that the use of film-holders reduces projection errors during intraoral radiographic exposures.

Geometric standardization of the images is critical for an accurate postoperative comparative radiographic assessment. However, even with the aid of film-holders, satisfactory radiographs might not be obtained because of possible difficulties in performing the radiographic technique and lack of patient cooperation (15, 16). Therefore, the interpretation of the radiographs taken over time during the follow-up period after dentoalveolar trauma might be compromised. This article describes a method for the geometric standardization of intraoral radiographs using a custom-made apparatus comprising a film-holder attached to an occlusal splint for the long-term follow up of cases of dentoalveolar trauma.

Case report

The procedure was performed in a 17-year-old male patient who suffered a severe dentoalveolar trauma because of a bicycle fall causing avulsion of both maxillary central incisors (Fig. 1a). The teeth were replanted at an emergency service after approximately 4 h in saline storage (Fig. 1b). No root surface treatment was performed. The following drug regimen was prescribed: ampicillin 500 mg (Eurofarma Laboratórios Ltda, SP, Brazil) every 8 h for 10 days; sodium diclofenac 50 mg (Novartis Biociências S/A, Taboão da Serra, SP, Brazil) every 6 h for 7 days; paracetamol 500 mg (Tylenol®, Janssen-Cilag, São José dos Campos, SP, Brazil) every 6 h in case of pain; and anti-tetanic vaccine. The replanted teeth were splinted for 30 days with a canine-to-canine retention made of 0.5-mm orthodontic wire (Dental Morelli Ltda, Sorocaba, SP, Brazil) and composite resin (TPH; Dentsply Indústria and Comércio Ltda, Petrópolis, Rio de Janeiro, Brazil) (Fig. 1b). The International Association of Dental Traumatology (IADT) guidelines for management of avulsed mature permanent teeth kept in media such as saline after extraoral dry time <60 min recommend applying a flexible splint for up to 2 weeks following replantation (2). However, a longer splinting time was used in the present case (around 4 weeks) because the viability of the PDL cells could have been affected due to the 4 h of storage in saline before replantation.

The endodontic treatment started 7 days after the trauma with changes of a calcium hydroxide intracanal medication every 15 days in the first 2 months and thereafter at 30-day intervals for 8 months. Calcium hydroxide therapy was carried out to retard the development of root resorption because the avulsed teeth did not receive any root surface treatment before replantation even after having remained in saline storage for 4 h. Definitive root canal filling was performed after this period of 2 months with a calcium hydroxide-based sealer (Sealapex; Kerr Corp., Orange, CA, USA) and gutta-percha cones (Tanari Industrial Ltda., Manaus, AM, Brazil) (Fig. 2). Follow up was planned with periodical returns for clinical examination and standardized radiographic assessment.

As the first step for preparing of the custom-made apparatus used in the present case for radiographic standardization in the follow-up period, a maxillary arch impression was made with alginate (Jeltrate; Dentsply Indústria e Comércio Ltda., Petrópolis, RJ, Brazil) and the model was cast in stone for fabrication of a 1.5-mm-thick acetate occlusal splint (Ultradent Products, Inc., South Jordan, UT, USA). Then, a Rinn X-C-P film-holder (Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) (Fig. 3a) was fixed to the occlusal splint with autopolymerized acrylic resin (Dencôr; Clássico Artigos Odontológicos Ltda., São Paulo, SP, Brazil) (Fig. 3b). To estimate the accuracy of the standardization procedure, a 5-mm-long piece of 0.7-mm orthodontic wire (Dental Morelli Ltda, Sorocaba, SP, Brazil) was also fixed to the occlusal splint with autopolymerized acrylic resin in the region corresponding to the distal face of the maxillary left central incisor

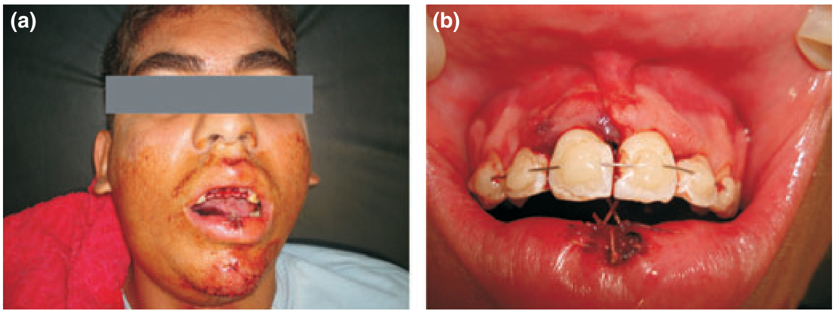

Fig. 1. Clinical images at the beginning of the treatment. (a) Frontal view of the patient showing absence of the maxillary central incisors; (b) intraoral view of the teeth after replantation and splitting.

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Fig. 2. Endodontic treatment of the replanted incisors.

(Fig. 3c). The orthodontic wire was placed in the vertical position in such a way that it would appear parallel to the long axis of the tooth in the radiographic images. The apparatus was disinfected with 1% sodium hypochlorite (Indústria Farmacêutica Rioquímica Ltda, São José do Rio Preto, SP, Brazil) 10 min before use.

Standardized periapical radiographs were taken 10, 16, 22, 28, 34, 40, 46, 52, 58, 64, 70 and 76 months after replantation (Fig. 3d). The radiographs were taken every 6 months to allow time to reduce patient exposure to radiation. Exposures were made with a dental X-ray equipment (Spectro II; Dabi Atlante S/A Indústrias Médico Odontológicas, Ribeirão Preto, SP, Brazil) operating at 70 kVp and 8 mA, using Ektaspeed films (Eastman Kodak Company, Rochester NY, USA) with 0.3-s exposure time. The radiographs were developed by manual processing according to the time-temperature method (Kodak Dental Developer and Kodak Dental Fixer; Eastman Kodak Company, Rochester NY, USA) (Fig. 4) and were digitized with a flatbed scanner with transparency unit (HP Scanjet G4050; Hewelett-Packard Development Company, Palo Alto, CA, USA). Linear measurements of the length of the central incisors and the orthodontic wire were made on the digital images using the Digora system (Soredex Orion Corporation, Helsinki, Finland) (Table 1). The length of the central incisors was determined to verify the reproduction of the projection geometry of the exposures and the orthodontic wire served to assess accuracy during length estimations in the radiographs (Fig. 5). Comparison of the vertical measurements made on the 12 radiographic images taken over 66 months of survey revealed only small variations (0.1–0.6 mm), confirming that the method used for standardization of the radiographic exposures was accurate.

The outcome of this case revealed the success of the replantation procedure, as the central incisors remained in their sockets and did not present any kind of sensitivity or accentuated mobility (Fig. 6) after approximately 6 years. Radiographically, it was possible to observe only small areas of replacement resorption. It was possible to re-establish the masticatory function and aesthetics, avoid or at least postpone the need of implants or prosthesis, and reduce the psychological impact of tooth loss to the patient.

Discussion

Maintaining the standardization of intraoral radiographs, especially when long-term radiographic follow up is required, is a hard task because of the difficulty

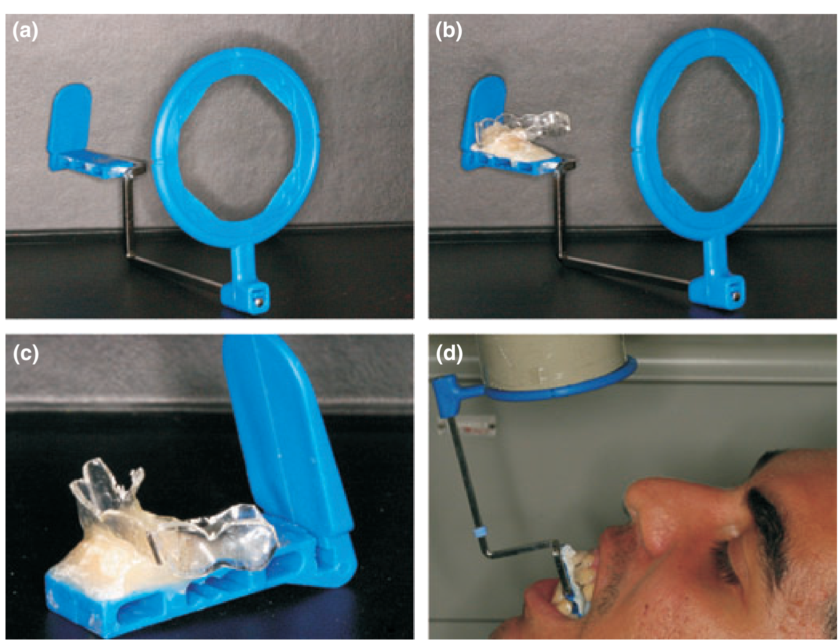

Fig. 3. Custom-made apparatus used in the case. (a) Rinn X-C-P film holder; (b) film-holder fixed to the occlusal splint; (c) detail of the orthodontic wire fixed to the occlusal splint in the region corresponding to the distal face of the maxillary left central incisor; (d) custom-made device in place for radiographic exposure.

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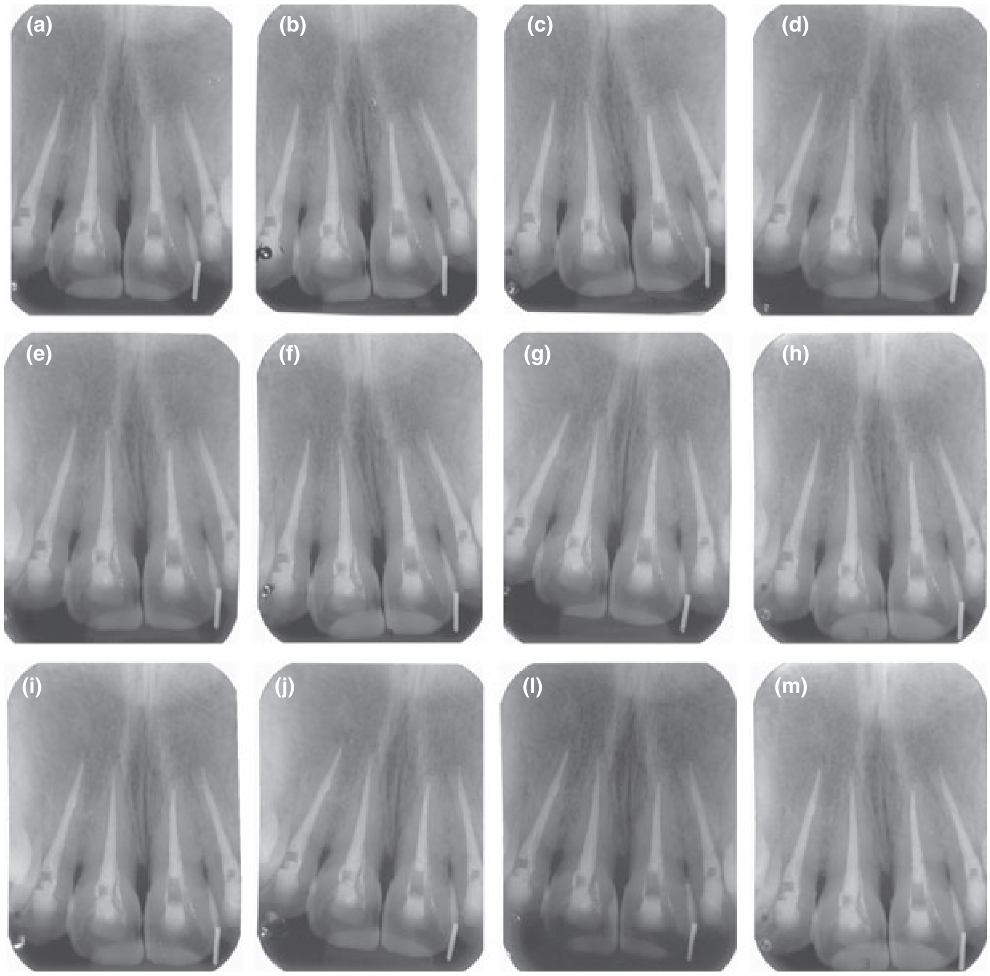

Fig. 4. Follow-up radiographs taken 10 (a), 16 (b), 22 (c), 28 (d), 34 (e), 40 (f), 46 (g), 52 (h), 58 (i), 64 (j), 70 (l) and 76 (m) months after the trauma. The piece of orthodontic wire can be seen in all images close to the distal face of the maxillary left central incisor.

Table 1. Measurements of the maxillary central incisors and orthodontic wire (mm) at the different follow up intervals

	10 months	16 months	22 months	28 months	34 months	40 months	46 months	52 months	58 months	64 months	70 months	76 months
Wire	5	5.1	5	4.9	4.9	5	5	4.9	5	4.9	4.9	5
Tooth 11	25.7	25.8	26.2	25.9	26.1	25.9	26	25.8	26.1	26.2	25.7	26.1
Tooth 21	24.1	24.6	24.6	24.2	24.5	24.7	24.7	24.4	24.3	**24.1**	24.3	24.7

in producing radiographs over time that have the same projection geometry. Several conditions, such as dental wear, new restorations and tooth movement, may alter the adaptation between the tooth and the film-holder, for example, compromising the diagnostic interpretation of radiographs in terms of reliability and accuracy (18).

When evaluating the use of methods for standardization of radiographic examinations, other aspects should be considered in addition to system reproducibility. Hausmann et al. (9) demonstrated that an electronically guided alignment device was capable of detecting bone alterations using subtraction radiography. Dove et al. (10) and Dornier et al. (11) found good specificity and sensitivity using computer-assisted systems with non-standardized radiographic images. Although the reproducibility of different systems has been demonstrated, they still have a high cost.

Knowing that the cementoenamel junction on radiographs is often used as a reference point in the assessment of alveolar bone loss and that vertical angulation of the X-ray beam has a direct influence on the image of the cementoenamel junction relative to the alveolar bone crest (19), the use of film-holder in intraoral radiographs has been highly recommended for the radiographic survey of periodontal status (20, 21).

Limitations of the radiographic examination like two-dimensional projection and interposition of bone

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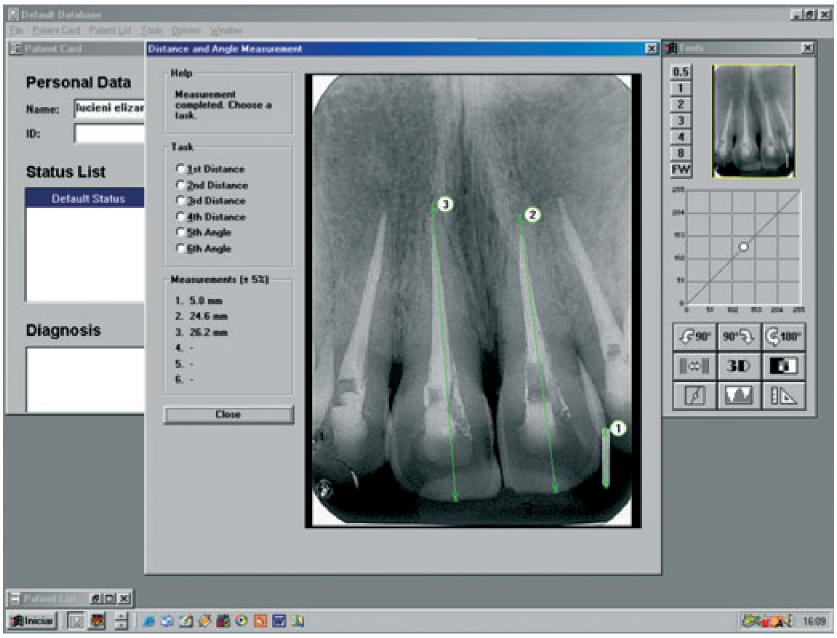

Fig. 5. Linear radiographic measurements of the length of the central incisors and the orthodontic wire made with the Digora system.

Fig. 6. Clinical aspect of the case after 76 months of the trauma.

cortical plates causing superposition of images should be taken into account as they could mask discrete bone alterations. Other factors that have a direct influence on the quality of the radiographic image, such as contrast, density and X-ray beam angulation, should also be considered (22), as they may reduce the precision of the diagnosis based on radiographic findings. Radiographic projection errors are hardly distinguishable from biological alterations (21) and may cause distortion of the image of the cementoenamel junction, alveolar crest, periodontal ligament space and lamina dura, compromising the validity of radiographic measurements and interpretation.

Multiple radiographic exposures with different angulations using the paralleling technique increase the capacity to determine the exact location of a bone defect (23). According to Van der Stelt (24) and Mikrogeorgis et al. (25), the use of this technique for radiographic acquisition is recommended to obtain images with good quality and high level of reproducibility. There seems to be a consensus that the use of the paralleling technique with film-positioning devices offers a reliable and valid method for determination of alveolar bone crest height (26, 27). However, changes in the tooth/film-holder distance may hamper image reproduction.

This way, the method described herein using a film-holder attached to an occlusal splint was developed with the aim of offering a custom-made apparatus with low cost and ease of handling, which could be used for the geometric standardization of intraoral radiographic exposures when long-term follow up is required, such as in tooth replantation procedures. In the present case, this method demonstrated good reproducibility, with only small variations (0.1–0.6 mm) in the linear measurements (replanted teeth and orthodontic wire) made on the 12 radiographic images obtained along 66 months. These measurement variations could be due to distortion of the images, which still is a weak point of the existing commercial film-positioning devices, such as the one used in the custom-made apparatus evaluated in the present study (28).

One of the major problems in the follow up of replanted teeth is the difficulty in obtaining standardized radiographic images over time to evaluate tooth structures and supporting tissues. Extracting accurate information from radiographic controls is essential to determine treatment outcomes (2). Especial attention should be used with respect to the main complications that may arise after tooth replantation, namely pulp infection and periodontal ligament damage (29). Root resorptions are expected complications in replanted teeth. The type of root resorption developed after replantation is directly related to the integrity of the cementum layer, viability of the periodontal ligament cells, pulp condition, severity of the trauma and nature of the traumatic stimulus (1, 30).

Because of the limitations of conventional radiography, periapical lesions may pass undiagnosed in their initial stages (31). According to Gonda et al. (32), the presence of radiolucent areas in the root apex and adjacent bone should be considered as a pathogno-

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monic sign of inflammatory root resorption, which requires clinical and radiographic monitoring for adequate diagnosis and treatment (33).

Minimizing variations in X-ray imaging geometry resulting from exposure conditions is mandatory in the quantitative analysis of longitudinal radiographic small hard-tissue changes alterations after tooth replantation procedures. The method described in the present case uses a simple, low-cost and easy-of-handling device. Despite the good results obtained, it should be emphasized the importance of presenting new case reports and case series with this custom-made device or other methods for geometric radiographic standardization, widening the perspectives for further research in this field.

Conclusion

The method for the geometric standardization of intraoral radiographs using an occlusal splint and a film-holder provided a consistent reproduction of the geometric exposure parameters. It also allowed an accurate gathering of information from the radiographic images and can be a useful tool for use in the follow up of cases of dentoalveolar trauma.

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