



# Macroscopic and radiographic aspects of orthodontic movement associated with corticotomy: animal study

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## Abstract

**Introduction** To quantify the rate of tooth movement in two corticotomy protocols in an experimental model in rats through macroscopic and radiographic analysis.

**Methods** The animals were divided into three groups: orthodontic movement (CO), orthodontic movement plus corticotomy surgery (G2), and orthodontic movement and corticotomy surgery with decorticalization (G3). The euthanasia occurred in 7 and 14 days. The data were statistically analyzed ( $p < 0.05$ ).

**Results** The CO presented lower distance between the mesial surface of the first molar and the distal surface of the third molar when compared to the G2 ( $6.96 \pm 0.24$ ,  $p = 0.009$ ) and G3 ( $6.93 \pm 0.18$ ,  $p = 0.016$ ) in the macroscopic analysis. In the 7 days, there was no statistically significant radiographic difference between the three groups: CO ( $0.94 \pm 0.21 \text{ mm}^2$ ), G2 ( $1.05 \pm 0.27 \text{ mm}^2$ ), and G3 ( $1.08 \pm 0.27 \text{ mm}^2$ ). There was a statistically significant difference between CO ( $0.87 \pm 0.12 \text{ mm}^2$ ), G2 ( $1.00 \pm 0.12 \text{ mm}^2$ ), and G3 ( $1.11 \pm 0.14 \text{ mm}^2$ ) at 14 days. There was a statistically significant linear difference between the groups in all periods.

**Conclusion** Tooth movement and the region of interest were influenced by corticotomy, regardless of the surgical technique in the 14 days.

**Keywords** Animal model · Orthodontic movement · Corticotomy surgery · Decorticalization

## Introduction

With the evolution of orthodontics, increasingly, adult patients seek orthodontic treatment, but this type of patient is mainly concerned with esthetics (type of appliance) and duration of treatment. Therapy duration may be influenced by several factors, such as the complexity of malocclusion, the ability of the orthodontist, the patient's cooperation and the rate of tooth movement, the possibility of periodontal hyalinization, and lower alveolar flexibility compared with growing patients [1].

Increasingly, techniques are being developed to reduce this period of treatment, among which are the following: self-ligating bracket systems; wires with memory (NiTi); mechanical or physical stimulation of the alveolar bone, such as the use of direct electric currents or magnets; and surgical interventions or administration of local or systemic medications [2].

The corticotomy technique, or intentional injury of the cortical bone, which is limited to the cortical portion of the alveolar bone, with minimal penetration into the bone marrow [3], is a preferred surgical intervention. In orthodontics, corticotomies are indicated to accelerate corrective orthodontic treatment as a whole, to facilitate the execution of mechanically difficult orthodontic movements, and to potentiate the correction of moderate to severe skeletal occlusions [4–6]. Corticotomy, besides reducing the treatment period, is also indicated for patients with ankylosed teeth, who benefit significantly from this treatment. Prolonged orthodontic treatments have been associated with negative outcomes, such as increased risk of caries [7] and periodontal disease [8, 9], root

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resorption [10], and pulp reactions [11], while reducing the period of orthodontic treatment has the benefit of possibly minimizing these unwanted side effects and improving patient satisfaction and acceptance.

Animal studies have shown that when performing the association of corticotomy and orthodontic movement, a rapid initial tooth displacement occurs due to the increased rate of bone remodeling as a result of surgical intervention [2, 12].

As the applications of corticotomy in orthodontic treatment are being expanded, the studies in the literature are mainly based on clinical cases, with many variations in both the surgical and the orthodontic protocol. This study's author aimed to compare two surgical corticotomy protocols in an experimental rat model in order to verify if the increase of the tooth movement rate would be related to the different degree of extension of the surgical procedure and in different periods of time, by means of macroscopic and radiographic analysis.

## Materials and methods

### Sample distribution

A total of 60 Wistar rats (*Rattus norvegicus*, albinos), 90 days old and weighing 300 g, were obtained from UNESP Botucatu. The procedures for experimental manipulation were performed according to the Guide for the Care and Use of Laboratory Animals (ARRIVE), and the experimental protocol was approved by the Committee on Ethics in the Use of Animals (CEUA) no. 08/2015-CEUA/ICTCJSC-UNESP. The rats were randomly divided into three groups: the control group (CO,  $n = 20$ ), orthodontic movement; Group 2 (G2,  $n = 20$ ), orthodontic movement plus corticotomy surgery; and Group 3 (G3,  $n = 20$ ), orthodontic movement plus corticotomy surgery with decorticalization.

### Installation of the device for orthodontic movement

For the installation of the experimental orthodontic device and surgical procedure, the animals were anesthetized in accordance with Ferreira et al. (2017) [13].

A 0.10-mm stainless steel ligature wire was inserted into the interproximal space between first and second molars, which was connected to a 3-mm closed-coil spring made of CrNi. Then, two segments of 0.20-mm (Morelli, Sorocaba, SP, Brazil) wire were attached at the other end of the spring and connected to the lower incisors, causing a continuous force corresponding to a force of 40 g. The resin was placed over the wire in the incisors for protection. The release of force of 40 g on the first lower right molar (point of force application) and the lower incisors (anchor point) allowed the first molar to be mesialized. This procedure was performed on all groups.

## Surgical procedure

After installation of orthodontic device, the tricotomy of the masseter muscle region and disinfection of the area with 2% chlorhexidine digluconate were done. Then, a continuous incision of approximately 10 mm with a scalpel blade 15c was performed at the point of the labial commissure toward the angle of the jaw. The masseter muscle was dissected to expose the buccal cortical bone at the root region of the first lower molar. A corticotomy with two vertical and one horizontal incisions, by delimiting a U-shaped in the region of the lower first molar, was performed with a blade tip (W1-0-CVDentus) in a piezo-surgical device (DentSurgCVDentus Sao José dos Campos, SP, Brazil) under sterile saline solution irrigation (Fig. 1 a and b) for the G2 and G3 groups. However, in the G3 group after the delineation of the corticotomy, the decorticalization with spherical tip was performed inside U-shaped in the region. The muscle was sutured with Vicryl 4-0 thread, and the skin was sutured with 3-0 silk thread. (Fig. 1 c and d).

Subsequently, to control postoperative pain, the animals received a single dose of Ketoprofen 10 mg/kg subcutaneously. During the surgery, the animals were in perfect conditions and their recovered was great. After the installation of orthodontic device and surgery, the animal's supply was changed to powdered food.

The animals were euthanized at 7 and 14 days, and the hemi-jaws were removed and fixed in 4% buffered paraformaldehyde solution for 48 h. After that, the specimens were decalcified in 10% ethylene diamine tetra acetic acid solution and embedded in paraffin.

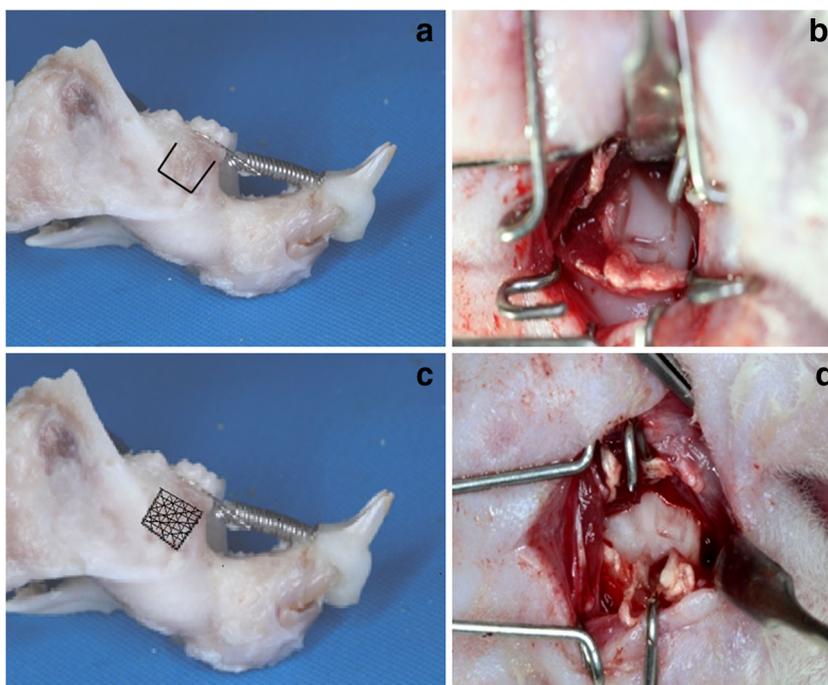
### Macroscopic measurement of the displaced area

To quantify orthodontic movement, a macroscopic measure comprised of the distance between the mesial surface of the first molar and the distal surface of the third molar was measured using a digital caliper (Digimatic-Mitutoyo, Telford, UK) together with the aid of a magnifying glass (Bio Art SP, Brazil) of  $\times 4$  magnification, improving the reliability of the method (Fig. 2a). Tooth movement was estimated by subtracting the mean of the repeated ( $2\times$ ) measures, as described by Hong et al. [14]. These measurements were performed 7 and 14 days after the animals were sacrificed.

### Radiographic image

Radiographic images were obtained with the Gendex digital X-ray using VinWix 2000 software. The digital X-ray apparatus was connected to a computer in which the

**Fig. 1** **a** Corticotomy U-shaped, **b** schematic drawing of corticotomy, **c** corticotomy U-shaped with decorticalization, **d** schematic drawing of the corticotomy with



images were recorded inside the VinWix 2000 program. The exposure time of the X-ray device was 0.040 s, and the focus–object distance was 30 cm. The piece was fixed at the ends with the modeling mass, taking care not to place it in the molars area and positioned as parallel as possible so that the cusps did not overlap (Fig. 2b, c).

All acquired images were exported in 8-bit gray-scale TIFF format for image analysis software (Image J 1.31p) to obtain the values for the region of interest (RI) to be studied. The linear measurement in the mesial of the first molar was also performed, from the cementum enamel junction to the top of the bone crest (Fig. 3).

### Statistical analysis

Statistical analysis was performed using software: SPSS V20, Minitab 16, and Excel Office 2010, with a significance level of 5%. The Kruskal-Wallis and Mann-Whitney tests were used for intra and inter-group analysis of the evaluated parameters.

## Results

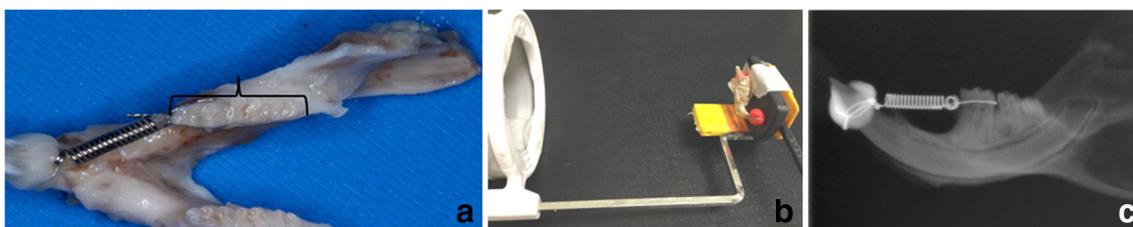
### Macroscopic analysis

The macroscopic analysis results are shown in Fig. 4. The intragroup comparison revealed a significantly higher distance between the mesial surface of the first molar and the distal surface of the third molar in the groups at 14 days when compared with day 7 ( $p = 0.011$ ).

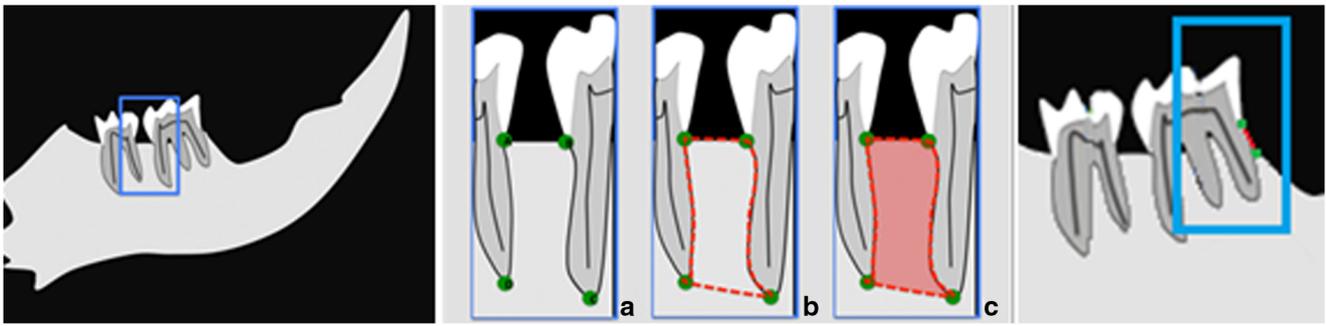
In the intergroup analysis, when the different treatments were compared, the CO ( $7.21 \pm 0.13$  mm) showed a lower distance between the mesial surface of the first molar and the distal surface of the third molar than the G2 ( $7.52 \pm 0.36$  mm,  $p = 0.009$ ) and G3 ( $7.36 \pm 0.13$  mm,  $p = 0.016$ ) on day 14.

### Radiographic RI analysis

The radiographic analysis results are shown in Fig. 5. In all experimental groups, there was no statistically significant difference on day 7. The CO group ( $0.87 \pm 0.12$  mm) showed a



**Fig. 2** **a** Macroscopic measure, **b** hemi-jaws in the digital X-ray apparatus, **b** and **c** radiographic images obtained with device orthodontic



**Fig. 3** Schematic drawing corresponding to the space between the roots of the mesial and distal dental elements, limits of the region of orthodontic movement, and linear analyses

lower radiographic area than the G2 ( $1.00 \pm 0.12 \text{ mm}^2$ ,  $p = 0.041$ ) and G3 ( $1.11 \pm 0.14 \text{ mm}^2$ ,  $p = 0.004$ ) at 14 day.

### Radiographic linear analysis

The linear analysis results of the mesial bone crest are shown in Fig. 6. There was a statistically significant difference between the groups at 7 and 14 days. G2 ( $0.36 \pm 0.16 \text{ mm}$ ,  $p = 0.041$ ) and G3 ( $0.570.29 \pm 0.22 \text{ mm}$ ,  $p = 0.003$ ) showed a higher linear measurement in the mesial of the first molar from the cementum enamel junction to the top of the bone crest than the CO ( $0.29 \pm 0.10 \text{ mm}$ ) at 7 days. At 14 days, the CO ( $0.30 \pm 0.09 \text{ mm}$ ) showed lower linear measurement than the G3 ( $0.50 \pm 0.17 \text{ mm}$ ,  $p = 0.004$ ).

### Discussion

Orthodontics, when associated with the surgical procedure of corticotomy, considerably shortened treatment time, due to the decrease in bone density and consequently the resistance to orthodontic movement. The magnitude of force applied in experiments for dental movement in a light and constant way and added to piezo incision is considered a minimally

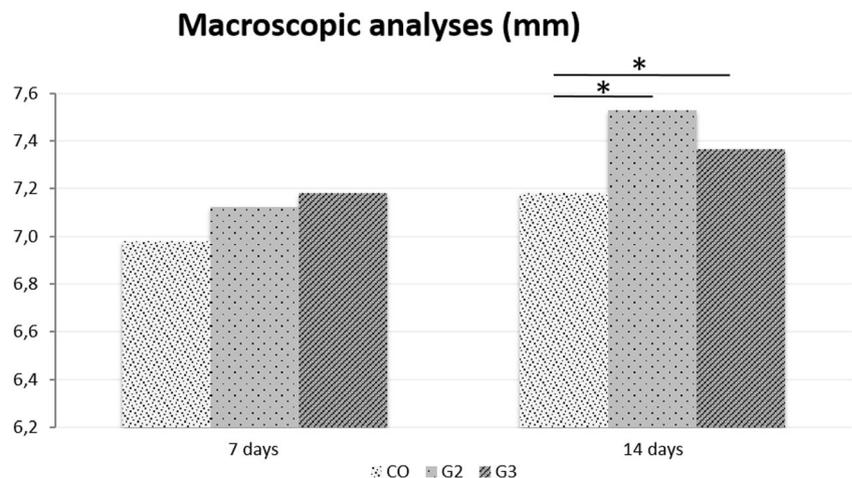
invasive surgical method when compared to conventional corticotomy [15].

However, based on the limited evidence available, the clinical significance of this temporary acceleration as part of treatment time is questionable. In addition, there are significant additional surgical costs associated with morbidity which, when combined with the short duration of the effect, renders the corticotomy application routinely unjustified [16].

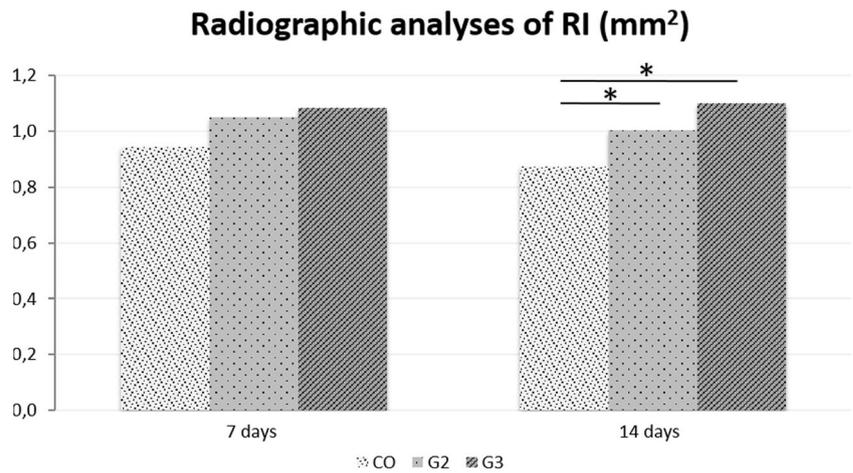
Through the methodology applied for induced tooth movement and the experimental model established in the literature [17, 18], it was possible to evaluate the behavior of the dental displacement with the different types of periods associated with surgical procedures.

In relation to the macroscopic analysis, it can be observed that the CO group, which received only the orthodontic appliance, presented inferior tooth movement values when compared to the G2 and G3 groups. This data confirms what was expected in this study, since corticotomy induced acceleration of orthodontic movement due to a regional acceleration phenomenon, characterized by transient and localized bone demineralization and exacerbation of bone remodeling [19]. This change in bone physiology would result in a localized decrease in the density of the trabecular bone, which, in turn, would offer less resistance to desired tooth movement [20].

**Fig. 4** Graphic presentation of macroscopic analyses of amount of tooth movement distance in days 7 and 14



**Fig. 5** Graphic representation of radiographic analyses of area in mm<sup>2</sup> in the days 7 and 14



The condition for ideal tooth movement combines well-planned orthodontic forces and alveolar bone that offers less resistance to movement, that is, with increased and less dense bone metabolism. When the metabolism of the alveolar bone is increased, the orthodontic movement is accelerated [21].

As the CO did not undergo this significant change in bone metabolism, it presented inferior results of tooth movement in both the 7 and the 14 days. There was no statistically significant difference between CO, G2, and G3 in the 7 days. On the other hand, the G2 and G3 presented higher values in comparison to the CO with a statistically significant difference in the 14 days, at which point the effects of the regional acceleration phenomenon were probably more intense.

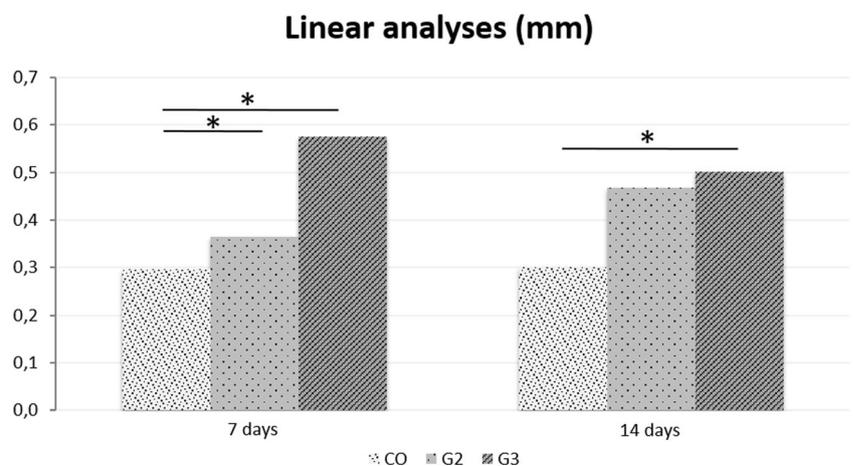
In the region of interest evaluated radiographically, it was noticed that there was no statistically significant difference between the groups in the 7 days. The CO presented slightly lower values of tooth movement in relation to the others. In the 14 days, once again, it is possible to observe that there was a statistically significant difference between the CO and G2 and G3. This happened after performing the corticotomy; the surrounding bone of the roots of the teeth temporarily undergo a demineralization or osteopenia, and a higher level of cellular

activity of fibroblasts, osteoclasts, osteoblasts, and cementoblasts in the periodontium, teeth, and bone surfaces is reported [22, 23].

This results in a more active bone and a remodeling of the periodontal ligament on the compression side and the tension side of the teeth [19], which allows the roots to move rapidly through the alveolar bone before they can remineralize [5]. Thus, the orthodontic movement was facilitated, and consequently, the area between the roots of the elements in question was increased in comparison to the CO, which did not receive any surgical procedure.

In the linear radiographic analysis in the period of 7 days, the CO differed from the G2, and G3, leading to the belief that in the initial periods of movement, the corticotomy would have a better result. In the 14-day, a statistically significant difference was observed between the CO and G3. Again, the highest values were found in the groups that received the corticotomies, since the orthodontic movement was accelerated due to the response to surgical trauma and on the compression side the mesial bone crest was resorbed, resulting in a distance from this to the cementum-enamel junction higher when compared to the CO, which in this same time period did not suffer a significant increase.

**Fig. 6** Graphic representation of linear analyses in mm in the days 7 and 14



New researches should be performed to confirm the results observed in this study regarding the indifference of the effect obtained with the more- and less-invasive corticotomy and thus determine the optimal surgical protocol. In addition, the long-term consequences of surgery related to possible undesirable implications in periodontal tissues should be studied. Thus, it will be possible to evaluate the real biological cost-benefit of this therapeutic approach and to provide greater safety for dental surgeons and their patients in choosing this intervention.

## Conclusion

It was concluded that tooth movement and the region of interest were actually influenced by the corticotomy-independent decorticalization in the 14 days. At 7 days, resorption of the mesial bone crest was higher in the decorticalization group.

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## Compliance with ethical standards

**Conflict of interest** Maria Aparecida Neves Jardim received research grants FAPESP; Nicole Berton de Moura received research grants FAPESP; the other authors declare that they have no conflict of interest.

**Ethical approval** Attached.

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