Influence of Endodontic Treatment and Retreatment on the Fatigue Failure Load, Numbers of Cycles for Failure, and Survival Rates of Human Canine Teeth

Taiane Missau, DDS, MD, Mariana De Carlo Bello, DDS, MD, PhD,† Carina Michelon, DDS, MD, PhD,† Pauline Mastella Lang, DDS, MD, PhD,‡ Gabriel Kalil Pereira, DDS, MD, PhD,§ Paolo Baldissara, DDS,¶ Luiz Felipe Valandro, DDS, MD, PhD,* Carlos Alexandre Souza Bier, DDS, MD, PhD,† and Marília Pivetta Rippe, DDS, MD, PhD**

Abstract

Introduction: This study evaluated the effects of endodontic treatment and retreatment on the fatigue failure load, numbers of cycles for failure, and survival rates of canine teeth. **Methods:** Sixty extracted canine teeth, each with a single root canal, were selected and randomly divided into 4 groups (n = 15): untreated, teeth without endodontic intervention; prepared, teeth subjected only to rotary instrumentation; filled, teeth receiving complete endodontic treatment; and retreated, teeth retreated endodontically. After the different endodontic interventions, the specimens were subjected to fatigue testing by the stepwise method: 200 N ($\times$ 5000 load pulses), 300 N, 400 N, 500 N, 600 N, 800 N, and 900 N at a maximum of 30,000 load pulses each or the occurrence of fracture. Data from load to failure and numbers of cycles for fracture were recorded and subjected to Kaplan-Meier and Log Rank tests ($P < .05$), in addition to Weibull analysis. The fractures of the specimens were classified as repairable or catastrophic. **Results:** The retreated, filled, and untreated groups presented statistically significantly higher fatigue failure loads and numbers of cycles for failure than did the prepared group. Weibull analysis showed no statistically significant difference among the treatments for characteristic load to failure and characteristic number of cycles for failure, although, for number of cycles, a higher Weibull modulus was observed in filled and retreated conditions. The predominant mode of failure was catastrophic. **Conclusion:** Teeth subjected to complete endodontic treatment and retreatment behaved similarly in terms of fatigue failure load and number of cycles to failure when compared with untreated teeth. *(J Endod 2017;43:2081–2087)*

Key Words

Endodontic treatment, fatigue resistance, retreatment, vertical root fracture

Significance

Fatigue resistance of filled and retreated canines was similar.

Tooth fracture has been considered the third most common reason for tooth loss (1). Further, endodontically treated teeth usually present a history of loss of coronal structure due to caries, fractures, and previous restorations (2). During endodontic treatment, additional dental structural removal is required for adequate access to the root canal and enhanced quality of treatment. While this procedure increases the predictability of success, it also reduces the ability of the tooth to resist masticatory forces (3). Huang et al (4) observed decreased dentin moisture and mechanical properties after endodontic treatment. Thus, it has been considered that endodontically treated teeth present a higher risk of biomechanical failure when compared with normal teeth (5).

Vertical root fracture (VRF) is a serious clinical complication that may result in the extraction of a tooth or, in cases of multirooted teeth, the resection of an affected root (6). This type of fracture can be caused by microscopic cracks propagating in areas of stress concentration (7). Consequently, endodontic procedures can be considered the major factor contributing to the development of VRF (8). The existing literature elucidates that, during mechanical/chemical instrumentation (9), root canal filling (10) and endodontic retreatment (11) defects may be introduced (ie, micro-cracks) on dentin, which, under mechanical stimuli (masticatory forces), may predispose the tooth to this type of fracture (VRF) (12).

Regarding endodontic retreatment, to guarantee the effective disinfection, instrumentation, and filling of root canals, the complete removal of preexisting filling material

From the *Prosthodontic Unit, Department of Restorative Dentistry, and †Endodontic Unit, Department of Stomatology, Faculty of Odontology, Federal University of Santa Maria, Santa Maria, RS, Brazil; ‡Department of Conservative Dentistry, Faculty of Dentistry, Federal University of Rio Grande do Sul, Porto Alegre, RS, Brazil; §MSciD Program, School of Dentistry, Meridional Faculty–IMED, Passo Fundo, RS, Brazil; and ¶Prosthodontic Unit, Department of Biomedical Sciences, Oral Rehabilitation Unit, University of Bologna, Bologna, Italy.

Address requests for reprints to Marília Pivetta Rippe, Federal University of Santa Maria, Faculty of Odontology, Prosthodontics Unit, R. Floriano Peixoto, 1184, Santa Maria, Rio Grande do Sul State 97015-372, Brazil. E-mail address: mariliarippe@mail.ufsm.br

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is mandatory (13). Hence, clinicians should be extremely careful during retreatment procedures to avoid further loss of and damage to dentin (14), because it has been shown that there is a direct correlation between the amount of dentin removed and the strength of the root (15).

Another factor that predisposes to VRF in endodontically treated teeth is the continuous incidence of intermittent occlusal loads during mastication. According to Roulet (16), *in vitro* fatigue studies are effective in simulating the effects of mastication on the occlusal surfaces of teeth. Indeed, Barreto et al (17) have shown that mechanical cycling associated with apical pressure filling techniques resulted in the occurrence of VRF in extracted single-rooted teeth. However, substantial data regarding this topic (fatigue behavior of endodontically treated teeth) are still lacking.

The position of the tooth in the arch also must be considered in relation to VRF, because loading parameters (eg, intensity and direction) are different from those for anterior and posterior regions. VRF is more frequent in molars (from 53% to 84%) than in premolars (from 16% to 33%) and is rarely found in anterior teeth (18), however, anterior teeth must resist both lateral and shear forces, which should be well-distributed in the crown and root to prevent fractures. Consequently, the mechanical demands on this group of teeth increase (18), especially when canine teeth are considered, because they play a fundamental role in the guidance of lateral excursion masticatory movements (malocclusion of posterior teeth) (19).

Thus, based on these aforementioned concepts, knowledge of the mechanisms of tooth fracture (occurrence of VRF) and of the mechanical fatigue behavior of endodontically treated teeth remains incomplete. Although some studies (5, 20, 21) have shown that the susceptibility to root fracture of endodontically treated teeth is greater than that of untreated teeth, until now no study has investigated the influence of endodontic procedures (instrumentation, filling, and especially endodontic retreatment) on fatigue outcomes.

Therefore, the objective of this study was to evaluate the fatigue failure load, numbers of cycles for failure, survival rates, and the modes of failure of canines subjected to endodontic treatment and retreatment. The null hypothesis was that there would be no difference among the experimental groups for these outcomes.

Materials and Methods

Selection of Teeth

This study protocol was submitted to and approved by the Ethics Committee of the Federal University of Santa Maria (UFSM) (Ethics Approval Number 612.855).

Sixty extracted human canine teeth were selected from among those available at the Teeth Bank of the Federal University of Santa Maria. First, all teeth were inspected, and any soft tissue and/or calculus present was mechanically removed with the aid of a hand scaler (Gracey curette ½; HuFriedy, Chicago, IL). Only teeth with a single root canal, straight root, complete root formation, and an intact crown were selected. Proximal radiographs were taken to confirm the presence of only 1 root canal. All roots were observed by stereomicroscopy at ×10 magnification (Zeiss Stemi SV6; Carl Zeiss, Göttingen, Germany) for the detection of preexisting cracks or fracture.

Under a stratified randomization that considered 2 factors ("treatment" and "size of the anatomical diameter of the root canal"), the selected teeth were randomly assigned among 4 groups by means of Random Allocation Software 1.0 (M. Saghaei, MD, Isfahan, Iran) (n = 15) (Table 1). To prevent dehydration, all teeth were stored under purified filtered water moisture (Asfer, São Caetano do Sul, São Paulo, Brazil) at 4°C, before the experimental procedures.

Control Group (Untreated)

Because this group received no intervention and remained as a baseline comparison group, it was kept stored only to prevent dehydration, as previously described, until the execution of the fatigue tests.

Root Canal Instrumentation

First, the pulp chambers of the teeth of the prepared, filled, and retreated groups (Table 1) were accessed by means of diamond burs (#1014; KG Sorensen, Cotia, São Paulo, Brazil) coupled to high-speed dental handpiece, under abundant water irrigation. The working length (WL) was determined with a #15 K-file (Dentsply Maillefer, DeTrey GmbH, Konstanz, Germany) by the subtraction of 1 mm from the length when it became visible at the apical foramen.

After the determination of the WL, teeth were embedded in a chemically cured acrylic resin (Dencrilay; Dencril, Caieiras, Brazil) with the aid of plastic cylinders (dimensions Ø = 25 mm × h = 15 mm) and an adapted surveyor to ensure parallelism to the vertical plane. The roots were embedded in resin up to 3 mm apical from the most coronal portion. Root canal instrumentation was executed with the ProTaper Universal rotary system (Dentsply Maillefer) equipped with an electric motor (X-Smart; Dentsply Maillefer) under a 2 N/cm torque and a constant speed of 300 rpm, where the S1, S2, and SX instruments were consecutively used for instrumentation of the cervical and middle root canal portions and the S1, S2, F1, F2, F3, and F4 instruments were used to prepare the apical portion until the complete WL was achieved (22). Between instrument uses, the canals were washed with 3 mL of a 2.5% solution of sodium hypochlorite (NaOCl) (Biodinâmica, Ibiporã, Brazil) applied by means of a syringe with a NaviTip irrigation needle tip (Ultradent, Köln, Germany).

Finally, root canals were washed with 2 mL of 17% ethylenediaminetetraacetic acid (EDTA) (Biodinâmica) for 3 minutes, then rinsed with 2 mL of distilled water and dried with #40 paper-points (Dentsply Maillefer).

Filling

Only the teeth of the "filled" and "retreated" groups received endodontic filling, executed by the lateral condensation technique, with AH Plus sealer (Dentsply Maillefer) and gutta-percha cones (main cone: #40, Dentsply Maillefer; accessory cones: D1, diameter 0.3 mm, 0.04 taper).

TABLE 1. Experimental Design and Mean (±SE) of the Load (in N) and Number of Cycles for Failure

Groups	Experimental procedures	Load for failure	Cycles for failure
Untreated	Untreated teeth, without endodontic intervention	506.7 (±46.2) A	77595.2 (±13924.3) A
Prepared	Endodontic preparation (ProTaper Universal rotary system)	386.7 (±35) B	39793.3 (±9584.9) B
Filled	Endodontic preparation + obturation (lateral condensation)	473.3 (±20.6) AB	65530.1 (±6939.2) AB
Retreated	Endodontic preparation + obturation + endodontic retreatment + obturation	520 (±22.2) A	79346.7 (±7416.2) A

Different capital letters indicate a significant difference (p = 0.05) among groups.