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THE DOCTOR-PATIENT RELATIONSHIP FACING THE MUTUAL ASSUMED RISK CONCERNING VERTICAL ROOT FRACTURE. A NARRATIVE REVIEW – PART 2

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Abstract: ***Background.*** The vertical root fracture (VRF) is a longitudinal one, starting and developing at dental root level. For a period, diagnosis is presumptive, due to nonspecific and moderate-intensity symptoms, confirmation requiring extraction of the tooth. Since the loss of the tooth represents for both dentist and patient a treatment failure, the ensuing disappointment can be expressed in the form of claims with medico-legal issues.

Objective. To assess the doctor-patient relationship concerning the risks involved by vertical root fracture, starting from the etiology and diagnosis possibilities of such an occurrence.

Materials and methods. To analyze this subject, several biomedical databases were inquired - PubMed, Web of Science, Embase, Cochrane Library - using combinations of terms appropriate to the subject.

Results. Endodontic treatment engenders dentin root alterations affecting the structure of the tooth, thus increasing the susceptibility and risks of VRF development. In such circumstances, the doctor-patient partnership can be severely shaken if the patient has not fully understood the risks and consequently exclusively attributes the failure to the doctor. In this relationship, the doctor's communication skills are of paramount importance.

Conclusions. Awareness of the clinical and therapeutic factors that favor the occurrence of vertical root fractures by doctors and patients alike prevents the appearance of possible subsequent disagreements, informed consent playing the role of holding both the doctor and patient accountable to prevent a possible accusation of malpractice.

Keywords: doctor-patient relationship, risk awareness, vertical root fracture, endodontic treatment.

INTRODUCTION

Vertical root fracture (VRF) is an unwanted event that occurs, unlike any other type of fracture, silently and manifests discretely at a certain time interval. There are multiple implications of a VRF for the patient, certain circumstances being able to generate forensic disputes. The first part of the review presented the results on the prevalence, pathogenicity and diagnosis of VRF. This second part addresses the implications of the endodontic treatment stages, of the root canal filling and also those implied by the endodontic retreatment stages and the restorative methods and the role they play in the occurrence of VRF.

Endodontic treatment

Endodontic treatment is responsible for several microstructural changes in dentin and changes in mechanical properties [22]. 90% of the organic dentin matrix and 30% of the dentin volume consists of collagen fibers. Dentin collagen considerably contributes to the mechanical properties of dentin. Changes in the connections between collagen fibers contribute to the fragility of endodontically treated teeth. As the composition, mechanics and physiology of this tissue vary over time, its properties change [23]. The loss of dental pulp vitality influences the hydration level of the dentin and iatrogenic factors associated with different surgical procedures may thus increase the susceptibility to VRF of endodontically treated teeth [22].

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Structural and morphological characteristics

The variations of the mechanical properties between the different types of dentin are to explain the propagation of VRF depending on the root morphology. An example of this is the "butterfly effect," an optical phenomenon that occurs in some cross-sections of the root canals (Fig. 3a), attributed to sclerosis of the dentinal tubules. The decrease in the number of dentinal tubules, thus allowing a greater transmission of light, giving add translucent appearance corresponding to the wings of the butterfly. This effect has been observed in teeth of all age groups and at all the root levels [24]. It is assumed that this aspect predisposes to the appearance of fissures in the buccal-oral direction (Fig. 3b) due to the significantly higher hardness in the medio-distal direction, 73% [25]. The presumption is based on studies that have reported the appearance of cracks in the buccal-oral direction on the root surface after surgery (Fig. 3c) in such teeth. The frequency of cracks was higher when ultrasonic tips were used during apicoectomy [24,25].

In vitro studies have shown that the isthmus is a favorite place for fractures. Although in a third of cases the fracture line did not involve the isthmus, the study concluded that this is a naturally vulnerable plan for development of VRF [26]. The flexural strength of the root depends on the distribution of dentinal tissue around the canal wall (quantity and type), root canal geometry and canal volume are important factors in terms of fracture resistance [9,26]. The external morphology of the root, the thickness of the dentinal wall and the shape of the canal affect stress distribution and determine the fracture dynamics. The stresses generated inside the root canal are dissipated on its surface canal and may become critical in the initiation and propagation of a crack that later - under the action of laterally directed occlusal forces – develop into a VRF [9]. Finite element analysis and clinical studies confirm the preferred buccal-oral direction of VRF with involvement of the buccal wall (93.8%), even in the case of incomplete fractures [9,22,28].

The effect of root canal instrumentation

The structural changes on the dentin surface are generated as mechanical and chemical effects during cleaning and shaping of the root canal. Modern endodontics involves the use of endodontic instruments made of Ni-Ti alloy driven by endodontic motors that convey a continuous rotational motion. The Ni-Ti alloy allowed flexible endodontic instruments even at a large taper, which facilitated a safer and more efficient preparation of the root canals. The endodontic motors give these instruments (at low speeds and controlled torque) a complete rotational movement. The structural characteristics of endodontic instruments depend on their geometric shapes and therefore various models aim to reduce the risk of instrument fracture.

Several studies have analyzed the performance and effects on the dentinal wall, analyzing the effect of the preparation technique, taper, speed and torque, the force developed at apical level and file geometry [3,4,10,11,18,23]. Progress through heat treatment applied before the manufacturing or during the post-manufacturing process allowed an improvement in flexibility while increasing strength, making it possible to use these instruments in a endodontic reciprocating movement. This kinematics reduces the stress of the

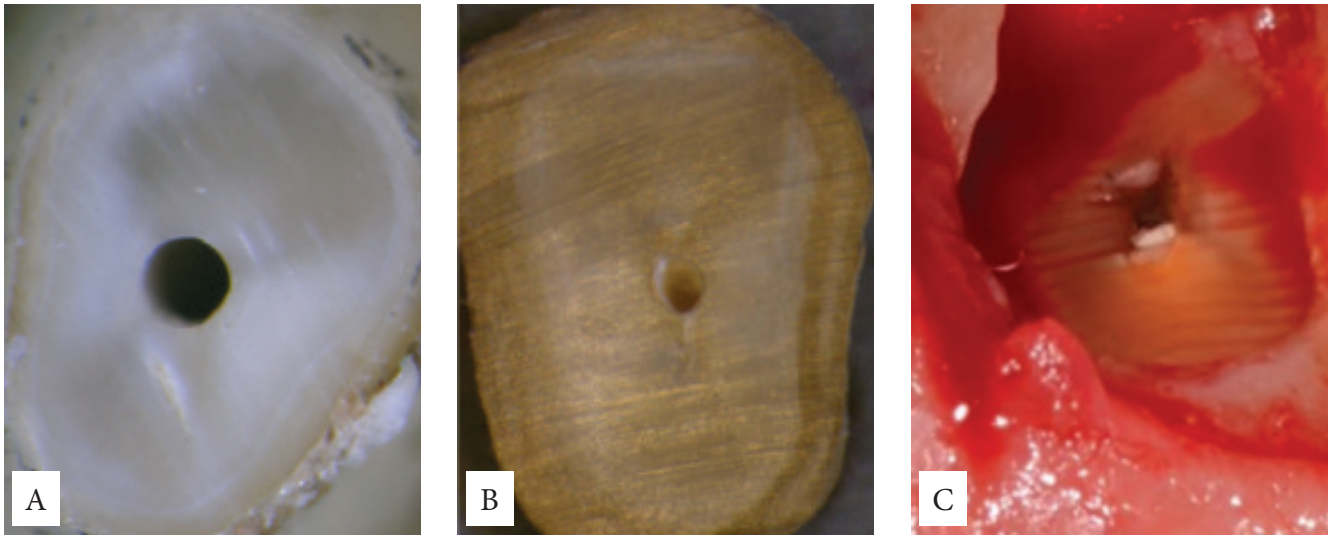

Figure 1. A. The "Butterfly Effect"; B. The initiation of the fissure in the lingual direction; C. Apical resection of the fracture line is observed on the sagittal dentinal section.

instrument in the cutting action (counterclockwise) but also clockwise (release of the instrument) and improves the resistance to cyclic fatigue that accumulates in the continuous rotational movement [3].

An impressive number of *ex vivo* studies have analyzed the performance of these instruments. The rotary instrumentation of the root canals generated more cracks at the apical level compared to manual instrumentation, aspect that was associated with the development of higher forces. Studies have shown damage to the dentinal wall precursors of a VFR, the area most involved being the curvature of the root canal [3,4,23].

Comparative studies of kinematics have had contradictory results on the rate of onset of dentinal defects, some of them claiming that the reciprocating motion is more conservative than the rotary one [4]. Other studies found no differences [3,29,30].

Curved canals require a preview of the cervical third of the root canal to allow a more accurate approach. The high taper in this area of Ni-Ti files has been found responsible for the increased risk of microcracks and the spread of fractures. A consequence of the fact that a uniform distribution of stress in rotational motion or the development of lateral forces in the reciprocal motion is not ensured [30,31,32]. Progress in the metallurgical process of obtaining Ni-Ti alloys, and the transition from instruments made of M-wire alloy. Instruments made of alloys with controlled memory, CM-wire or CM-EDM, significantly reduced the occurrence of dentinal defects even in the instrumentation of curved canals [33-35].

The effect of endodontic irrigant

The endodontic irrigant has both a mechanical role - facilitating root canal shaping - and chemical and microbiological ones by antibacterial action on organic and bacterial residues present into the root canal [37]. It is also the only way to impact those areas of the root canal walls that are not affected by mechanical instrumentation. The NaOCl solution in variable concentrations (from 0.5%, 1%, 2.5%, 5.25%) is the most used endodontic irrigant due to its antibacterial effect. This is directly correlated with concentration, time of action, temperature, and mode of activation. NaOCl has a predominant impact on the dentinal organic matrix (consisting predominantly of type I collagen) because it is a nonspecific proteolytic agent. Chlorination of the final protein groups breaks the long peptide chains, affecting the mechanical properties of dentin [37]. NaOCl can penetrate the inorganic component (hydroxyapatite), which has long been thought to protect the organic component due to the small molecular size of hypochlorous acid or hypochloric anion [38]. Several studies have shown that NaOCl solution degrades the physical properties of dentin: flexural strength, tensile strength, elastic modulus, and micro-hardness. Concentration is the main factor influencing dentin deproteinization [39]. Some experts believe that none of these properties directly determines the resistance to fracture of the teeth [27]. Concentration, activation, and time decisively influence the reaction rate of NaOCl with dentin [22,23,25,37-40].

EDTA is a chelator with an effect on the inorganic component of dentin. The chelating action exerts on the intertubular dentin at a depth of 1- 5 μm and on the peritubular dentin up to 20 μm [38], facilitating the effect of NaOCl on the organic matrix. The effect on the dentinal wall is erosion [23,38] and reduction of micro-hardness [23]. The use of chelators associated with rotary instrumentation did not diminish the appearance of microcracks on the dentinal wall [3]. The use of EDTA followed by NaOCl has a stronger erosive effect than the NaOCl sequence followed by EDTA [38,41]. The combination of NaOCl with EDTA decreases the antimicrobial activity of NaOCl. The alternative use of EDTA and NaOCl in high concentrations has caused concerns because it potentiates the chemical damage of dentin through repeated cycles of demineralization and deproteinization [42]. Some *ex vivo* studies have concluded that the alternative use of NaOCl and EDTA had a lesser effect on the surface resistance of a tooth treated in vitro than the exclusive use of NaOCl [41,43]. Dual Rinse® HEDP (Medcem Switzeland) combines the mild chelating action of ethidric acid or bisphosphonic acid (1 hydroxyethylidene) with NaOCl to obtain an irrigant that retains the antimicrobial properties of NaOCl [44] and erosion is similar to those obtained by 3% NaOCl followed by EDTA [45]. The effects on the mineral or organic components of chlorhexidine have not yet been fully uncovered. The remaining antimicrobial effect of CHX 3% has been demonstrated by numerous studies [23,38,44,46].

The effect of intracanal medication

In endodontics, calcium hydroxide is used mainly due to its antimicrobial and dentinogenetic properties. In vitro studies have shown that the intracanal use of $Ca(OH)_2$ for prolonged periods negatively affects the properties of dentin, namely dentin sputum and fracture resistance. The mechanism responsible for this effect on dentin is not well understood. It is assumed that the alkaline pH of $Ca(OH)_2$ induces neutralization

and dissolution of proteins and protein-bound glycans generating the decomposition of collagen [23]. The period of intracanal use of $Ca(OH)_2$ can be harmonized with the endodontic diagnosis and managed so that the benefits are not minimized by the risk of dentin weakening.

Antibiotics used as medication between treatment sessions can change the color of dentin. The tetracyclinic component can attach to dentin, causing the color to change, first yellow after 2 to 4 weeks and then turning gray [23]. In endodontic regeneration, a triple antibiotic paste (TAP) containing metronidazole, ciprofloxacin and minocycline is used. Minocycline is a 2nd generation tetracycline that induces dentin dyschromia and caused dentin demineralization [23]. As a result, double antibiotic paste (DAP) containing only metronidazole and ciprofloxacin has been proposed. In some antibiotics acids are added to maintain chemical stability, control tonicity or to ensure physiological compatibility. Studies have shown that long-term exposure of dental hard tissues to acidic antibiotics can cause demineralization and adversely affect their mechanical properties. In vitro studies have shown that the three-month application of TAP, DAP and $Ca(OH)_2$ significantly reduces the fracture resistance of mandibular premolars compared to one week of application [47].

Root canal filling

Excessive forces applied to the root canal walls during lateral or vertical condensation of gutta-percha have been identified as a major factor in the formation of VRF [2,23,25,48]. The occurrence of bleeding in the canal around the gutta-percha after hearing of a sharp sound are the clinical manifestations of a VRF produced during the sealing maneuvers of the root canal [25]. A series of *ex vivo* studies analyzed the correlation of several parameters: the size of the apical master cone, preparation taper, the working length and the initiation of fractures when performing the root canal filling. In the technique of lateral condensation of gutta-percha, a shorter working length resulted in a lower frequency (26%) of VRF [49]. The standardized single cone techniques did not influence the development of VRF even in the presence of existing apical cracks and due to the rotary instrumentation technique [31]. The lateral or vertical condensation of gutta-percha did not influence the frequency of VRF in the *ex vivo* study by Adorno *et al.* [50]. Root canal shaping is responsible for generating cracks in the apical area, while sealing techniques have a significant effect on their propagation [50]. Practitioners are to be careful not to exert excessive forces when using spreaders or pluggers during gutta-percha condensation maneuvers, especially when using higher taper.

Certain sealers used in root canal filling may improve root resistance due to their adhesive properties. Resin materials such as Resilon (Resilon Research) and EndoREZ (Ultradent) allow, in the opinion of some specialists, to obtain an endodontic monoblock structure. They give a significant resistance to VRF compared to classic sealants [25]. The use of MTA in root canal fillings increases the resistance of teeth to VRF [50]. It is considered that MTA induces mineralization inside the dentinal tubules and thus protects the dentinal walls against the propagation of cracks induced by various factors [52]. Encouraging results have also been reported in the use of MTA for treatment of VRF [53], but the subject still needs to be investigated.

Endodontic retreatment

Root canal retreatment meaning the penetration or disassembling of existing restorations and removal of the canal filling. After cleaning the canal, the endodontist carefully exams the root canal and then fills and seals with a new root canal filling material. Once the endodontic retreatment is performed, a new restoration is placed to protect and restore the tooth to its full function.

Sometimes the presence of posts or core materials prevents direct access to the endodontic space. The disassembling or removal of these devices in order to gain access to the root canal is performed with specially designed systems. Specially dedicated loops attached to ultrasonic devices can also be used to withdraw posts or core material from the canal. No studies have been conducted in this regard, but such an approach can generate the occurrence of dentinal cracks or even a VRF. Post space preparation can reduce dentin thickness and adds a certain degree of fracture risk. Post removal increases the chance of developing an VRF in a vulnerable tooth. The conclusion of one of the few studies on this topic is that retreatment procedures and additional instrumentation in resumption procedures of endodontic treatment, can cause the initiation of cracks and the spread of fractures in the apical dentin [31].

The drawing out of the canal filling material is done with ultrasonic loops, sets of rotating or manual endodontic files. As with endodontic treatment, studies have shown that the kinematics used for endodontic retreatment induce cracks in the root dentin [31,

54]. Rotating kinematics generated more apical cracks compared to reciprocating kinematics [55]. Reciprocating systems are superior in terms of the efficiency of removing sealers and gutta-percha [56].

Chloroform, halothane, and xylene used as guttapercha solvents cause changes in dentin micro-hardness after 5 minutes exposures [23]. Such solvents have to be used in small quantities and for short periods of time. Some of them also have carcinogenic potential.

Apical surgery associated with endodontic retreatment (apicoectomy) increases the frequency of VRF to 62.31% compared to orthograde retreatment where a frequency of 31.16% is reported [57]. A large clinical trial with a follow-up period of 8 years, categorically established the association between retreatment and VRF [19]. The conclusion of this study is clear: "a tooth undergoing endodontic retreatment has an eight times higher risk of developing a VRF than a tooth with primary root canal treatment" [19].

Coronal restoration of endodontically treated teeth

Restoration of endodontically treated teeth the amount of remaining hard dental structure, root morphology (length, width, and curvature of the roots), the position of the tooth on the arch, antagonistic teeth, and occlusal relationships [12]. Ideally, restoration materials should have compressive strength that gives them resistance to occlusal forces, the coefficient of thermal expansion like dentin, high adhesion to the remaining tooth structure, minimal water absorption and caries-protective effect [58].

Regardless of the method and the chosen coronal restoration material, depending on the amount of outstanding hard structure, situations require the placement of an intraradicular post. Posts have been used in current practice for a long time and can be made of various materials such as metal, zirconium, carbon, composite resins. In functional dynamics, masticatory forces are exerted in the form of compression in the molar area and shear at the anterior teeth, and the presence of a post distributes masticatory stress in the long axis of the tooth [59]. When stress is not exerted on the long axis of the tooth, stress accumulates and concentrates in the root walls. Studies have shown that the placement of a post made of a rigid material (metal, zirconium, titanium) predisposes to root fracture.

Fiberglass-reinforced resin posts (FRC) are preferred in current practice because they ensure a relatively uniform distribution of stress in the root dentin, reducing the risk of root fracture [59]. Adhesive cementation is the only chance to stop the development of VRF after preparing the endodontic space necessary to insert a post.

Clinical studies have shown the development of VRF in teeth treated endodontically and indirectly restored in 74.1% of cases [19] and specifically those restored with crowns and without posts in 33.2% [60]. Indirect restorations were associated with VRF in 25.8% of cases [60]. Interestingly, the higher frequency of VRF in the case of single-tooth restorations is 91.3% [60]. Concerning the above controversies [61] the correlation between the occurrence of VRF and the kind of restoration performed (direct/ indirect) is governed by the correct restoration of occlusal relations. The occlusal design and restoration of the points of contact with neighboring teeth allow a reduction in the magnitude of the stress. Possible elimination functional interference and management of parafunctions are a priority in restoring endodontically treated teeth and preventing the development of vertical root fractures.

DISCUSSION

Endodontic treatment as it results from the analysis performed, can produce changes in the physical characteristics of the dentin. Accordingly, the dentist should explain to patients the implications of these changes, including the increased risk of VRF. With perseverance and tolerance and in a detailing manner, the practitioner explains how the physiological changes in the dentin combined with the effects of endodontic treatment and retreatment to some extent make the tooth vulnerable. The informed consent of the patient supported a perfect understanding of the risks and their assumption.

Endodontically treated teeth it is accepted are less resistant. Removing the dental pulp, which with dentinal fluid absorbs and distributes part of the masticatory stress, there is a slight dehydration of the dentin [27]. The biodynamic behavior of dentin depends on an optimal balance between rigidity (mineral component) and dynamic strength (collagen and hydration). Once the dental pulp is removed, there is also a loss of water (9%) from the structure of the dentin [27]. Aging generates the same changes in the biodynamics of dentin. Clinical studies have shown an increase in the incidence of VRF in endodontically treated teeth after 40 years [19,49]. Bio structural changes of the dentin during age cumulated with the reduction of hardness and fatigue resistance. The bio structural changes of the dentin due to aging are

cumulated with the reduction of hardness and fatigue resistance. The doctor and patient must be aware of these aspects. The following endodontic treatment represents the basis of the doctor-patient partnership.

The determining factor in the appearance and propagation of FVR is represented the occlusal forces, which in the case of endodontically treated teeth are above the usual limit. Stress is not felt the patient as in vital teeth, due to proprioceptive and nociceptive changes in endodontically treated teeth. This aspect must be emphasized and inserted in the discussion with the patient, and it represents a prevention factor in the occurrence of FRV.

In the case of a VRF, it is preferable to preserve and analyze the fractured root, which can provide valuable information in the event of a dispute. The multitude of factors corroborated with accidental or parafunctional occlusal overloads of endodontically treated teeth can cause a vertical root fracture, without considering the effects of the coronal restoration.

In conclusion, endodontic treatment modifies root dentin and affects the structure of the tooth. Endodontically treated teeth are more prone to fracture. The VRF is favored by the accumulation of several minimal changes in the root dentin that can become critical under the action of occlusal forces. The selection of cases and the responsible management of the treatment prevent the appearance of VRF. All these aspects are known and assumed by the endodontist after a proper information of the patients and with their consent. "Saving teeth" is a risk taken by both endodontist and patient, which they should not forget in the unfortunate and unlikely event of a vertical root fracture. Lack of patient information and consent may lead to legal complications, exposing the dentist to a possible malpractice indictment.

Conflict of interest

The authors declare that they have no conflict of interest.

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