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The Effect of Canal Curvature on The Deformation and Fracture Rate of Nickel-Titanium Rotary Endodontic Files (An In Vitro Study)

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Introduction

Since the end of the nineteenth century, automated root canal instrumentation has been available, but systems had many problems. The challenges of increased canal blockage, instrument breakage, and insufficient canal debridement were related to the use of stainless steel instruments and have been dramatically improved with the introduction of nickel-titanium files.

The first useable alloy was developed by William Buehler in 1960 at the U.S. Navy Ordinance Lab in Silver Spring, Maryland. Walia et al. investigated the feasibility of using this alloy in the fabrication of endodontic files, and showed that nickel-titanium files had two to three times the elastic flexibility in bending and torsion, as well as superior resistance to torsional fracture when compared with stainless steel files of the same size. These features led to better centering of the instruments within the canal, less straightening of the canal, fewer elbows and ledges, and less transportation.

Fracture was a major concern associated with the introduction of nickel-titanium files especially in curved canals where many tensile and torsional stresses could be created. This situation might adversely affect the goals of treatment and ends to dramatic results as perforation, surgery or failure.

Research laboratories concentrated their efforts to improve hindrances associated with the use of nickel-titanium alloy and in the same time to reach its optimum performance.

Consequentially, many systems were introduced to the market with widely different tactile sense, fracture resistance, cutting efficiency, flexibility, and avoidance of transportation based on their design features.

ProTaper and K3 systems were major popular brands used in this study to evaluate the effect of canal curvature on their fracture, bending and deformation under controlled conditions.

Review of literature

It is the necessity of the man to reach the perfection that the development of the technology has come progressing unimaginable ideas someday demonstrating once again his ability to solve the problems[1] .

The commercial research houses unfold everything feeding us with the best alternatives. They bomb to us products that appear at one time as the panacea and at brief moment stood out by the introduction of others with new characteristics and so on becoming a circle never to finish[2].

Over the years, the revolutionary development of incorporating nickel-titanium into endodontic files has greatly transformed the methods of root canal instrumentation. They help minimize the undesirable complications often encountered during instrumentation in fine and curved canals [3].

The concepts of cleaning and shaping of the root canal system established by Schilder make up, together with tridimensional obturation, the basis of endodontic therapy. For straight root canals, the stages of cleaning and shaping are relatively simple procedures, but the preparation of curved root canals may lead to ledging, perforation, or even instrument separation[4].

Generally, these procedure failures are caused by the trend of the endodontic instrument to return to its original straight form when inserted into a curved root canal, due to the rigidity of the materials used for its manufacturing. Previously the preparation of root canals was carried out with carbon steel reamers, which in addition to their low flexibility had low resistance to corrosion. The corrosion problems were solved with the use of stainless steel instruments [5], but the elastic modulus of these materials is still relatively high, and the occurrence of failures during instrumentation of curved root canals continued to depend exclusively on the expertise of the endodontist [6].

In 1988, ***Walia et al*** introduced a new material for the manufacturing of endodontic instruments: the nickel-titanium orthodontic wire [7]. The nickel-titanium alloys, with an approximately equiatomic composition, have in addition to high resistance to corrosion and excellent biocompatibility some special features: the shape memory effect and super elasticity. The shape memory effect occurs in specific conditions in which the metal is deformed at a certain temperature in an apparently permanent way, but it recovers its original form when moderately heated. The super elasticity is a particular case of the shape memory effect in which the shape recovery temperature is lower than the temperature of deformation. This means that shape recovery happens immediately after deformation interruption and load withdrawal. The term super elasticity is related to the fact that the recoverable strain obtained is much higher than that which may develop in the elastic strain regimen of metals. Both the shape memory effect and the super elasticity are associated with the occurrence of a phase transformation in the solid state that has special characteristics: the martensitic transformation, which may be induced by the application of stress and reversed by moderate heating of the material [8].

However, despite the evident advantages of the new technique, Ni-Ti rotary instruments may undergo failure by fatigue when used in curved canals [9].

It is believed that the breakage of endodontic rotary instruments takes place in two different ways: due to torsion or to fatigue through flexure [10]. Breakage due to torsion occurs when the point or any other part of the instrument binds in the canal while the chuck keeps on turning until the instrument exceeds the elastic limit of the metal, thus producing a fracture. This type of breakage has been associated with the application of excessive apical force during instrumentation [11]. Breakage due to fatigue through flexure occurs because of metal fatigue. In this case the instrument does not bind in the canal but rotates freely until the breakage occurs at the point of maximum flexure [12].

Intracanal separation of the rotary files is a serious concern in modern endodontic practice. Removal of the broken fragment may not be feasible and may jeopardize the outcome of root canal treatment [13].

It is desirable to remove or bypass a separated instrument, but if neither of these corrective procedures can be performed, periradicular surgery may be the only other endodontic option [14]. Depending on the pulpal status and degree of contamination of the root canal system, the broken file may result in a compromised prognosis for the tooth [15].

Many studies using simulation models have attempted to describe the events that occur during rotary preparation. The results that have been reported are directly related to each study's method of use. However, it should be understood and appreciated that the best techniques and the desired result will only be achieved through a great deal of practice [9, 16].

Although successful root canal treatment depends on many factors, preparation is one of the most important steps because it determines the efficacy of all subsequent procedures [17]. However, during the last decade several new types of continuously rotating instruments were introduced. The evolution from hand to engine-driven techniques was facilitated by manufacturing rotary instruments from nickel–titanium with its array of special properties [9] and it appears that with the increased application of these instruments in contemporary endodontic practice, fractures have become more prevalent [18]. The fracture potential of an instrument rotating in a curved canal becomes greater as the angle of curvature increases and the radius of curvature decreases [19].

I- Nickel–titanium alloy:

In the early 1960s, a nickel–titanium alloy was developed by W.F. Buehler, a metallurgist investigating nonmagnetic, salt resisting, water-proof alloys for the space programs at the Naval Ordnance Laboratory in Silver Springs, Maryland, USA [20]. The thermodynamic properties of this intermetallic alloy were found to be capable of producing a shape memory effect when specific, controlled heat treatment was undertaken