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DEFESA DE TESE

INSTRUMENTOS ENDODONTICOS DE NÍQUEL-TITÂNIO: ANÁLISE DE DEFEITOS ANTES E APÓS O USO ATRAVÉS DA MICROSCOPIA ELETRÔNICA DE VARREDURA.

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Resumo

Tecnicamente todas as etapas são cruciais para obter-se excelência no tratamento endodôntico. Visando a minimizar acidentes durante a realização do preparo químico-mecânico, modificações nos métodos de instrumentação e nos instrumentos endodônticos de níquel titânio têm sido sugeridas. Novos instrumentos são muitas vezes lançados no mercado sem o devido conhecimento de suas propriedades e limitações, portanto o objetivo desta tese foi avaliar os defeitos de superfícies dos instrumentos reciprocantes *Unicone* e *Prodesign,* comparando-os aos instrumentos de rotação contínua *Prodesign S e Wizard Navigator*. Cada sistema foi utilizado três vezes, em canais simulados, e as superfícies dos instrumentos foram analisadas através da microscopia eletrônica de varredura. Após análise estatística dos resultados, concluiu-se que os instrumentos reciprocantes *Prodesign* e *Unicone* apresentaram aumento progressivo de defeitos de superfície, o que sugere utilização única para maior segurança durante o tratamento. Os instrumentos de rotação contínua *Wizard Navigator* e *Prodesign S* apresentaram menores defeitos após o terceiro uso em relação a deformação das espiras, porém estes instrumentos apresentam uma tendência maior a perda de material da superfície. Adicionalmente uma revisão de literatura foi realizada com intuito de abranger os achados dos últimos anos sobre sistemas recíprocos e contínuos.

Abstract

Technically all steps are crucial to obtain excellence in required endodontic treatment. To minimize accidents during the preparation chemical and mechanical changes in the methods and instrumentation in nickel titanium endodontic instruments has been suggested. New instruments are often launched on the market without proper knowledge of their properties and limitations, therefore, the purpose of this thesis was to evaluate the defects in surfaces of instruments reciprocantes Unicone and Prodesign, comparing them to the instruments of continuous rotation Prodesign S and Wizard Navigator. Each system was used three times in simulated root canals and the surfaces of instruments were analyzed by scanning electron microscopy. After statistical analysis of the results, it was concluded that the instruments reciprocantes Prodesign and Unicone presented a progressive increase of surface defects, suggesting that single use for increased security during the treatment. The instruments of continuous rotation Wizard Navigator and Prodesign S presented smaller defects after the third use in relation to flute deformation, but with a trend to enhance material loss. In addition, a review of the literature was performed to cover the findings of recent years on reciprocal and continuous systems.

SUMÁRIO

INTRODUÇÃO

O tratamento endodôntico envolve uma série de etapas que necessitam ser cuidadosamente executadas para que as chances de insucesso sejam mínimas. Por mais criteriosa que seja feita a terapia e por mais qualificado e treinado que seja o profissional a executar, falhas no tratamento podem ocorrer por fatores que fogem ao alcance do especialista, como por exemplo, persistência de microrganismos no interior do sistema de canais radiculares, devido à complexa anatomia interna destes, comprometimento imunológico do paciente e defeitos imperceptíveis em instrumentos, que podem levar à fratura durante a etapa do preparo químico-mecânico.

Tecnicamente todas as etapas são cruciais para obter-se excelência no tratamento endodôntico. Não se pode imaginar uma boa obturação, um bom selamento final, sem um bom preparo químico–mecânico, que por sua vez, precisa ser facilitado pela localização de todos os canais principais, que dependerá de uma abertura adequada permitindo uma boa visualização e acesso aos instrumentos. No entanto a fase de instrumentação ainda representa a que mais demanda tempo e cautela, pois é necessário fazer um desgaste ao longo de todo o canal principal para viabilizar a ação das substâncias irrigadoras e medicações intracanais, sem desviar o trajeto original e muito menos deixar a estrutura fragilizada com excessos de desgaste.

Limas de níquel-titânio (Ni-Ti) começaram a ser desenvolvidas na instrumentação de canais radiculares a partir da década de 80[1] e consequentemente muitos benefícios foram obtidos ao longo destas últimas décadas. Devido a sua elasticidade estes instrumentos possuem uma maior capacidade de manter a centralização do preparo aumentando a qualidade e reduzindo o tempo de trabalho[2]. Por outro lado, possuem alto grau de fragilidade e com o uso continuado podem apresentar deformações na estrutura metálica da liga, normalmente imperceptíveis clinicamente[3,4]. Como resultado pode-se

observar desde um comprometimento na eficiência do corte, levando a uma modelagem e limpeza inadequada até o favorecimento de fratura destes instrumentos gerando insegurança para o uso repetido pelos profissionais.

Visando a minimizar esses problemas e a evitar acidentes durante a realização do preparo químico-mecânico, modificações nos métodos de instrumentação e nos instrumentos endodônticos têm sido sugeridas. Novos instrumentos com diferentes ligas, formatos, conicidades e tipos de movimentação, têm surgido com o objetivo de obter um preparo do canal radicular de forma apropriada com uma ampla abertura coronária e um estreitamento a nível apical. Instrumentos de níquel-titânio podem ser usados em movimento rotatório contínuo ou em movimentos de reciprocidade.

Os instrumentos são muitas vezes lançados no mercado sem o devido conhecimento de suas propriedades e limitações. Neste particular, o conhecimento da morfologia dos instrumentos em uso é de suma importância para conhecer seus possíveis defeitos e as maneiras de contorná-los.

O objetivo deste trabalho foi avaliar a alteração de superficie dos novos instrumentos endodônticos usados em movimentos recíprocos do sistema *Unicone* e *Prodesign*, comparando-osaos sistemas de movimentos contínuos*ProDesignS e WizardNavigator*. A análise qualitativa e quantitativa foi realizada antes e após o uso dos instrumentos, através do microscópio eletrônico de varredura (MEV). Adicionalmente uma revisão de literatura foi realizada com intuito de abranger os achados dos últimos anos sobre sistemas recíprocos e contínuos.

ARTIGO 1:

Reciprocating versus Rotary instruments: A review

Abstract

Literature started to point out essential parameters involving reciprocating instruments through clinical and laboratory essays. Looking into apical debris extrusion, incidence of instrument breakage, canal centering ability, apical zipping, a myriad of information has become available. Therefore, a review of current literature may collect recent findings and help practitioners about this novelty. The aim of this review is to revisit the literature and compare reciprocal and continuous rotation techniques. Reciprocating systems are similar in some aspects in comparison to rotational systems, with regards to cleaning ability, centered preparations, reduction of *Enterococcus faecalis* and dentine defects. On the other hand, being single use and enhanced resistance to fatigue, together with novel methods to treat the alloy may lead to the thought that reciprocal systems are an excellent aid to root canal preparation. However, more needs to be understood about this new era of instruments to verify, long term and especially *in vivo*, the success and failure when these instruments are used.

Introduction

The popularization of use of nickel-titanium (NiTi) instruments for root canal preparation has brought greater predictability of this important phase of root canal treatment. Super-elasticity is the key for the superior properties of this alloy when compared to stainless steel instruments [1]. Engine-driven systems became a reality and constantly new systems are being launched in the dental market.

The risk of instrument fracture is probably the greatest disadvantage of NiTi regular use. If not removed, the piece that became retained may impair proper root canal system disinfection and cause failure [2,3].

The first rotary NiTi system was proposed by Dr. John McSpadden and reached the dental market in 1992. These instruments had 0.02 taper. In 1994 he added 0.04 and 0.06 tapers, which changed the ISO previous paradigm [4]. From then, various systems were used in a multitaper approach. The advantages were still not enough to avoid instrument fracture occurrence, A new type of instrumentation was suggested, based on alternated movement, known as reciprocation.

The principle of reciprocal movement is similar to a watch-winding hand motion, being used first with stainless steel instruments in 1958. Initially the available motors would alternate rotation equally clock and anticlockwise in 90^0 angulations. Later, new motors would allow smaller angulations of 30^0 clock and anticlockwise [4]. In 2008, a new concept of reciprocation was proposed by Dr. GhassanYared, using only one NiTi instrument, which at that stage was a 25/0.08 Protaper, and the clock and anticlockwise movements would alternate with different angulations for each move [5].

The proposed technique had a wide acceptance amongst endodontists, because it was advantageous with lower cost and time, as well as cyclic fatigue. The instrument in this technique should be used only once [6].

Staring from 2011, new systems were launched in the market, with new materials and designs, bringing up new perspectives of use in endodontology. Literature started to point out essential parameters through clinical and laboratory essays. Looking into apical debris extrusion, incidence of instrument breakage, canal centering ability, apical zipping, a myriad of information has become available. Therefore, a review of current literature may collect recent findings and help practitioners about this novelty. The aim of this review is to revisit the literature and compare reciprocal and continuous rotation techniques.

Cleaning and shaping

Shaping ability deriving from a preparation technique, either under rotary or reciprocating movement may influence the other steps of endodontic treatment: irrigation and root filling. Root anatomy, especially curvatures, is changed by endodontic instruments, with a tendency of rectification; however, ledges, zipping and other problems may arise and impose difficulties to the removal of infected tissue which could lead to failure. Predictability is one of the major aspects to be considered in root canal preparation.

You *et al* [7] assessed Protaper shaping ability under continuous and reciprocating modes. They measured root volume, curvature and surface area through microtomography. They could not find differences between the techniques even with severe curves apically. Similarly, Franco *et al* [8] tested FlexMaster system in Rotary

and reciprocal movements. Minimal differences were found; Root centering ability was better with reciprocation.

Bürklein*et al* [9] tested the cleaning ability of Reciproc and WaveOne, which are reciprocating, compared to rotary MTwo and Protaper. They found that the four systems were efficient in maintaining root curvature. Rotary MTwo and reciprocating Reciproc seemed to perform better at cleaning the root canal walls. Apparently the movement did not influence the final result. Various other studies compared cleaning and shaping abilities using different instruments of rotation and reciprocation, such as Protaper, Mtwo, WaveOne, Reciproc, Twisted File, OneShape, F360, but they all allowed satisfactory preservation of original shape and limited differences between techniques [10,11,12].

Debris compaction and apical extrusion

Whenever a new instrumentation method is launched, it is expected that it is able to face contamination and cause minimal injury to periapical tissues, providing a favorable condition to repair and/or healing. These aspects are influenced by the ability of the instrument to remove organic debris and not compact them.

Although single instrumentation with reciprocating techniques perform faster, the amount of debris removal seems to be reduced [13,14]. Therefore one should consider the use of multitaper rotary instrumentation when preparing canals with high incidence of isthmuses and protrusions.

It is very unlikely that one can avoid apical debris extrusion, independently of the technique. This may lead to flare-ups. Al-Omari and Dummer [15] state that balanced force techniques reduce apical debris extrusion when compared to linear and continuous movements.

Bürklein and Schafer [16] compared apical extrusion from reciprocating WaveOne and Reciproc vs rotary Mtwo and ProTaper. They found that all systems caused apical extrusion, but rotary instrumentation had lower levels of extrusion. This contrasts with other studies that found better results with reciprocating instruments [17,18].

Reduction of *Enteroccocus faecalis*

One of the main purposes of root canal treatment is microbial reduction and prevention of recontamination of the root canal system. *Enteroccocusfaecalis*is commonly found in cases of persistent apical periodontitis and is associated with endodontic treatment failure [19].

Ferrer-Luque*et al* [20] tested *Enteroccocusfaecalis* reduction using Mtwo, Twisted File and WaveOne, collecting samples form root canal walls with paper points before and after instrumentation. Statistically reduction ability was not significant amongst groups. WaveOne had higher percentage of reduction, probably because of the taper, 0.08 compared to 0.06 of the other instruments. Machado *et al* [21] and Martinho *et al* [22] used endotoxins to test reduction and again no statistically significant diferences were found.

Oval canals were used in the study performed by Alves *et al* [23]. They compared Reciproc and BioRace under molecular analysis using qPCR. They found both systems to be effective in reducing *Enterococcus faecalis.* Therefore the available literature may lead us to infer that the techniques under discussion do not interfere with the results on this bacterial species.

Canal Anatomy Interference

Canal volume is one of the variables used to assess dentine removal during root canal instrumentation. There is no consensus as to the ideal amount of dentine to be removed during preparation, but excessive instrumentation may lead to fragile root canal walls which could be more susceptible to fracture.

The amount of dentine to be removed in cervical and medium thirds should be enough to allow access to irrigating solutions to the apical third. When curvature comes into the equation, the final shape should allow rectification in such a way that stress is minimized and yet walls are kept strong enough to bear load and not fracture. At the apical third, especially at the foramen, preparation should not cause deviation or zipping and even perforations. These are associated with inefficient decontamination leading to persistent apical periodontitis.

Câmara et al. [24] assessed cross-sections of the three thirds of mesiobuccal canals prepared by one of three HERO systems (Hero 642, HeroShapers, Hero Apical), in continuous rotation. None of the systems was able to touch all the root canal walls. Another study [25] tested five Rotary systems and two manual systems (ProTaper, GT, ProFile, K-3, FlexMaster) and two manual NiTi systems (ProTaper, GT) as to the remaining dentine and canal diameter. Differences were not found amongst groups and all systems provided good preparation quality. Stern *et al* [26] tested the centering ability of Rotary Protaper and Twisted Files and Protaper in reciprocating movement. Centering ability was provided by all techniques.

Several studies have compared rotary and reciprocating systems as to the occurrence of apical transportation and centering ability. Gergi*et al* [27] compared Twisted File Adaptive, Reciproc and WaveOne, and found that Twisted File Adaptive showed the

least apical transportation. This system is used in rotation until the instrument finds resistance, shifting automatically to reciprocation until the instrument is free again, returning to rotation. Also, they found this system to better maintain original anatomy with better centering ability [28]. However, Nazari*et al* [29] found different results when comparing Reciproc and Twisted File Adaptive. According to this study, Reciproc provided less transportation than TF Adaptive.

Reciproc and MTwo have similar design, but one is meant to be used in reciprocation and the other in continuous rotation. In a study, MTwo seemed to provide greater apical transportation [30]. Other study compared Reciproc and BioRace and showed higher levels of transportation with the use of Reciproc [31].

A study assessed six #25 systems (OneShape, Pro Taper Universal, Pro Taper Next X2, Reciproc, Twisted File Adaptive, SM2WaveOne), finding no differences as to apical transportation, canal curvature and centering ability. Reciproc showed higher dentine removal ability [32]. OneShape, although showed lower centering ability, needed less time to prepare the canal than Reciproc and WaveOne [33].

The current literature does not provide solid evidence to infer that one system performs better to maintain original anatomy. Maybe centering ability is influenced by instrument design (taper, flexibility and cross-section). Operator factors, such as experience does not seem to influence quality [34, 35].

Dentine defects

The presence of microfractures and fissures in dentine may occur during instrumentation. The propagation of these defects by the incidence of repetitive load may lead to vertical fracture which may compromise tooth longevity. Bier *et al* [36] showed greater microfractures when teeth were prepared with rotary instruments as

compared to manual instrumentation. According to Kim *et al* [37] the occurrence of defects could be associated with high torque and tapers.

Bürklein*et al* [38] assessed dentine defects following the use of rotary Mtwo and Protaper vs reciprocating Reciproc and WaveOne. They found all techniques allowed the formation of defects, but this was more pronounced at the apical third with reciprocating instrumentation. On the other hand, Mahmoud *et al* [39] compared Protaper in rotation and reciprocation, and reciprocating WaveOne in oval canals. They found the least defects and highest resistance to fracture when using WaveOne. This was confirmed by other study [40] that found Protaper to be more aggressive to produce microcracks when compared to WaveOne or manual Protaper. Again, more needs to be produced by the literature to allow better understanding the behavior of these instruments towards dentine.

Resistance to breakage

Although NiTi has numerous advantages against stainless steel, breakage is currently one of the greatest worries of practitioners. Instruments break with no apparent alterations, which make it more difficult to prevent accidents.

Instrument failures may be torsional and flexural. Torsional failures occur when instrument tip is stuck somewhere in the root canal wall and the motor keeps rotating the instrument into its long axis. Flexural failure occurs at the curvature generated by repetitive cycles of compression and tension, causing repetitive changes in the microstructure until it breaks [41]. It is estimated that 70% of breakages are flexural,

There have been changes since the year 2000 in structure and treatment of NiTi instruments [43-47]. Thermal treatment is one of these changes. Also, nitrogen ion

implantation has improved mechanical properties of the instruments [48, 49]. New designs together with these changes are bringing new generations of instruments.

M-Wire is a new NiTi alloy, using a special thermal process. Some studies assessed the effect of this treatment on breakage. Gambarini*et al* [50] compared GTX that uses M-Wire with traditional K3, but did not find any difference as to resistance to fracture. However, other studies showed greater cyclic fatigue resistance using GTX compared to Profile, Endosequence and GT [51,52,53]. Bouska*et al* [54] compared two M-Wire systems (GTX and ProFileVortex) and three traditional systems (Twisted File, Endosequence and Profile). The best results were the ones using M-Wire technology followed by Twisted File.

A new development was the R-phase, which is an intermediate phase with distortion of the austenitic phase, as a result of the repetitive cycles of heating and refrigeration, generating a different format that is intended to enhance resistance to cyclic fatigue and superelasticity [47]. *Twisted file and* K3XF are amongst the instruments with this new technology. Pérez-Higeras*et al* [55] compared K3XF and traditional K3 and Twisted File. R-Phase instrument K3XF showed greater resistance to fracture independently of the use, either in rotation or reciprocation.

Several studies report better behavior against breakage when reciprocating movement is performed. De-Deus *et al* [56] compared Protaper F2 in simulated resin blocks in continuous or reciprocal rotation and reciprocation allowed greater resistance to breakage. You *et al* [57] tested these instruments in extracted teeth and found that Protaper F2 could be used at least six times more under reciprocation than rotation, and time for preparation was also reduced under reciprocal movement.

Twisted File and Reciproc were also assessed under reciprocal and rotational motions, being both much more resistant to breakage under reciprocation [58,59].

WaveOne and Reciproc are the most used reciprocal instruments. Comparative studies between these instruments found different results. Plotino*et al* [60] and Perez-Hilgueras*et al* [61] found better resistance to breakage with Reciproc. Pedulláet *al* [62] found no statistical significant differences, whereas Kim *et al* [63] found greater flexural resistance with Reciproc and greater torsional resistance with WaveOne.

Conclusions

Reciprocating systems are similar in some aspects in comparison to rotational systems, with regards to cleaning ability, centered preparations, reduction of *Enterococcus faecalis* and dentine defects. On the other hand, being single use and enhanced resistance to fatigue, together with novel methods to treat the alloy may lead to the thought that reciprocal systems are an excellent aid to root canal preparation. However, more needs to be understood about this new era of instruments to verify, long term and especially *in vivo*, the success and failure when these instruments are used.

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ARTIGO 2:

Reciprocating and Rotary NiTi instruments: SEM analysis of defect progression following uses

Abstract

Introduction. This study aims to assess instrument defect following repeated uses of new reciprocating instruments, *Unicone*and *Prodesign,* comparing with rotary instruments, *ProDesign S* and *Wizard Navigator.* To date, no study has compared these instruments as to surface characteristics and defect with use.

Methods. Sixty simulated canals were used. Each set of instruments was used to prepare three simulated canals. Following preparation, SEM analysis at 75x was performed and images were taken looking at: material loss, flute deformation and instrument fracture. Analysis was performed before and after each use.

Results. Reciprocating systems showed greater material loss following first use. At second use, the difference among systems was not significant. At third use reciprocating Prodesign had greater material loss than Unicone ($p=0.006$), Wizard Navigator ($p<0.001$) and Prodesign ($p= 0.001$). Flute deformation was significantly greater with reciprocating instruments Prodesign R and Unicone at all uses with no significant difference between them. Rotary systems Wizard Navigator and Prodesign S had very little deformation, with no significant difference between them.

Conclusions. Reciprocating instruments Prodesign (PR) and Unicone (U) have progressive defect scores, which suggest single use is the safest approach. Wizard Navigator (WN) and Prodesign S (PS) Rotary instruments showed less defects following third use especially as to flute deformation, but with a trend to enhance material loss.

Introduction

NiTi instrumentation has become popular as it enhances shaping speed and allows lower distortions along root canal curvatures. However, the continuous use of these instruments, especially in rotation, may cause structural defects which are not clinically perceptible (1). This could impair cutting efficiency and lead to inadequate cleaning and shaping or to instrument fracture, jeopardizing routine use of these instruments.

To minimize such occurrences and avoid accidents during root canal preparation, modifications of instrumentation techniques and instrument designs have been adopted. Together with that, alloy characteristics and treatments and rotational modes aim to provide control of taper and apical anatomy. A new system in the market, *Prodesign S* (Easy EquipamentosOdontológicos, Belo Horizonte, Brasil) suggests specific designs for specific functions, utilizing a sequence of four instruments, two orifice shapers (L1 and L2) with sizes of 30.10 and 25.08 respectively, a patency instrument (L3) sizing 25.01and a finishing instrument (L4) size 20.06 (2).

Other continuous rotation system, *Wizard Navigator* (Medin,Chirana, Czek Republic), is a sequence of six instruments of varying tips and tapers (L1-10.04, L2-15.05, L3-20.06, L4-25.06, L5-30.06, L6-25.07).

The motion has been subject of great interest as it apparently affects efficiency and safety of the instruments. NiTi instruments have two main modes of use: rotational or reciprocating. The latter has been currently debated extensively as to its advantages and limitations. It advocates the use of a single instrument using reciprocation to completely prepare the root canal (3). It is based on the balanced force concept (4) in which the instrument executes anti-clock and clockwise movements at varying angulations. Some studies claim reciprocal movements cause less cyclic fatigue when compared to continuous rotation (5,6).

The above mentioned companies, Easy and Medin, launched instruments for use in reciprocation, using tip and taper of 25.06 and 25.08, respectively. They are meant to be of single use. However, it is of general knowledge that many practitioners are tempted to repeat instrumentations using the same instrument.

Much of the novelty in instrument design and technique is launched in the dental market without proper investigation. Some of the currently available instruments have scarce literature about them.

This study aims to assess instrument defect following repeated uses of new reciprocating instruments, *Unicone*and *Prodesign*, comparing with rotary instruments, *ProDesign S* and *Wizard Navigator*, under Scanning Electron Microscopy (SEM).

Materials and methods

Group allocation was set considering the type of instrument and distributes as follows: PS Group (ProDesign S); WN Group (Wizard Navigator); PR Group (Prodesign); U Group (Unicone). For each group, five sets of the basic series was provided.

Sixty simulated canals made of clear resin (IM do BrasilLtda - São Paulo, Brasil), were used. Their diameter was equivalent to a size 10 instrument. Each set of instruments was used to prepare three simulated canals. Each simulated canal was wrapped ingauze and held in place by a vice (Vacu Vise, North Andover, MA, USA).

Preparation was performed, using electric motor (VDW Silver, VDW, Munich, Germany), with torque and speed, as well as the motion, reciprocating or rotary, according to manufacturers´ recommendations (Table 1).

Before each instrumentation, cleaning of the instruments was undergone with scrubbing using soft toothbrush (Oral B 35, São Paulo, Brazil) and sonicationin a Biocleaner tray (Biodont, São Paulo, Brazil) containing Riozyme II enzyme detergent (Rioquímica, São Paulo, Brazil) for 20 min (3). Instruments were sterilized in autoclave (Vitale, Cristófoli, Campo Mourão, PR, Brazil) at 1 atm pressure and 127 ^{0}C for 20 min.

Before and during preparation, the canals were irrigated with 1 mL anionic detergent solution (Tergensol; Inodon, Porto Alegre, Brazil) at each instrument change. The solution was injected intothe canal using a 1 mL luer-lock syringe (Ibrás, SãoPaulo, Brazil) with a 25/5 needle (Becton-Dickinson, São Paulo, Brazil). At each instrument change, cleaning of the flutes was performed with gauze soaked in detergent.

SEM (Scanning Electron Microscope) analysis was conducted with a Phillips XL 20 (Philips, Eindhoven, Netherlands) at 4 moments: before first instrumentation, following first, second and third instrumentation. Images of the instrument were recorded at 75x magnification. The following items were looked at: material loss, flute deformation and instrument fracture. A scoring system was adopted to allow observers to take notes using categories (Table 2). Two observers scored the condition of each instrument. The scores of flute deformaion and material loss were treated as Poisson variables and compared by Generalized Estimating Equations (GEE) test.

Results

Intraclass Correlation Coefficient (ICC) was 0.97 for flute deformation, 0.92 for material loss and 1.00 for instrument fracture. Figure 1 shows the progressive loss of material with use of the four systems, being more significant following first and third uses. Reciprocating systems showed greater material loss than continuous systems following first use. At second use, the difference among systems was not significant. At third use reciprocating Prodesign had greater material loss than Unicone ($p=0.006$), Wizard Navigator ($p<0.001$) and Prodesign ($p= 0.001$).

Figure 1 shows a progressive increase of material loss at the amount of four systems in use, being more significant after the first and third use. The reciprocating systems had higher scores than continuous systems after the first use. After the second use continuous systems exhibited loss of material similar to reciprocal systems. At the end of the third reciprocating use ProDesign system (PR) had the lowest loss of material when compared with systems UnicOne ($p = 0.006$), Wizard Navigator ($p <0.001$) and Prodesign S ($p = 0.001$).

Flute deformation was significantly greater with reciprocating instruments Prodesign R and Unicone at first, second and third uses with no significant difference between them. Rotary systems Wizard Navigator and Prodesign S had very little deformation, again with no significant difference between them (Figures 2 and 3).

There were no differences regarding instrument fracture. Out of 60 instruments, only two fractured, one of Unicone and other of Wizard navigator.

Discussion

Simulated canals have got their limitations as they do not resemble actual anatomical variations and dentin properties, but they are able to standardize canal variations, reducing biases, as reported in other studies (8,9,10). SEM analyses have also been adopted for studies using endodontic instruments (11,12,13). This study used similar criteria for instrument defect assessment as Troian et al (14).

The reciprocating single instrument concept has gained popularity in the endodontic field, as it is more attractive than the use of several instruments in continuous rotation. Besides being less costly, literature shows greater cyclic fatigue resistance when compared to rotary instruments (15,16,17,18).

Incidence of instrument fracture was low in this experiment, representing 3.33% of the samples. One occurred in a 25.06 Wizard Navigator rotary instrument during its first use and the other when using a 25.06 Unicone during its second use.

Advantages in discharging endodontic instruments after first use have been reported (19), as defects can occur when new instruments are used by experienced endodontists. Most manufacturers advise single use for NiTi instruments to allow safety. Shen et al (20) suggest single use for reduction of cyclic fatigue and to avoid cross-infection. On the other hand, this procedure elevates the cost of treatment especially in public services, sometimes giving place only to stainless steel files. Analysis of instrument surface before and after use provides useful information about structural changes and defect formation, allowing inferences about safety during clinical practice that may influence decision making processes. This study used instruments three times. Before each use, they were autoclaved, despite the use of simulated canals, to reproduce similar clinical scenarios.

The concept of single instrument preparation of root canal system in reciprocation (3) provides friction with dentin walls, once coronal flare is not used. This produces more defects than compared to rotary instruments when orifice shapers and more coronal instrumentation are provided before reaching apex. Material loss was greater in single use reciprocating Unicone than rotary instruments Wizard Navigator and Prodesign S. The reuse of instruments elevates the loss of material regardless the instrument mode.

Prodesign in reciprocating rotation (PR) showed lower values of loss of material, after third use, when compared to continuous rotation system Wizard Navigator ($p < 0.001$) and Prodesign S ($p = 0.001$), as well as compared to instruments of reciprocating alternating rotation UnicOne ($p = 0.006$). The superiority of PR instruments at the end of the third use. Previous thermal treatment of these instruments could explain this trend, although this was not within the scope of this experiment.

Mechanical properties of instruments are influenced by several factors. The way they are manufactured is diverse. Some instruments are preheated in about 400º C which modifies its metallic structure, resulting in more flexibility and less flexural fatigue (21,22). Torsional fatigue resistance is apparently not reduced (23,24,25), but the recovery to original features seems to be better when thermal treatment is performed (26). However, this should not be a reason for more than one use when reciprocal instrumentation is done.

Literature is provided as to instrument defects (27,28,29), but to date the comparison among these instruments was not provided. Several types of research questions have been raised, which allows little inferences about comparisons amongst studies. Standardization of studies could be of help to overcome this issue, as ultimately, the main remit of instrument research is to provide clinicians enough information for their clinical choices.

Conclusions

Reciprocating instruments Prodesign (PR) and Unicone (U) have progressive defect scores, which suggest single use is the safest approach. Wizard Navigator (WN) and Prodesign S (PS) Rotary instruments showed less defects following third use especially as to flute deformation, but with a trend to enhance material loss.

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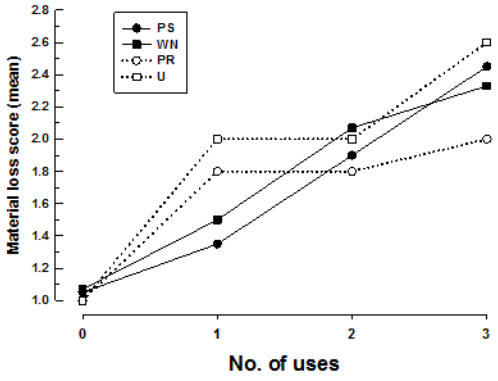
List of figures

Figure 1: Comparison among Wizard Navigator, Prodesign S, Prodesign R andUnicone, considering material loss (seen under SEM) according to number of uses .*p<0.05.

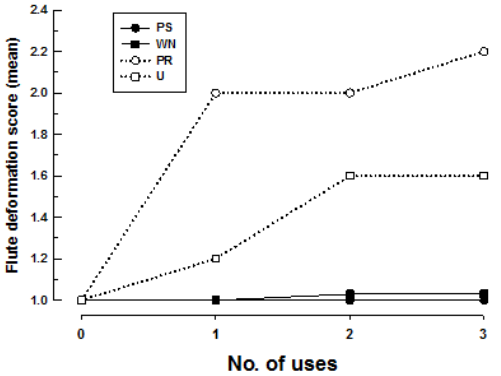
Figure 2: Comparison among Wizard Navigator, Prodesign S, Prodesign R and Unicone, considering flute deformation(seen under SEM) according to number of uses .*p<0.05.

Figure 3: Sequence of images taken before and after each instrumentation with reciprocating instrument Prodesign R. SEM – 75x a: before first use; b: first use; c|: second use; d: third use.



Material Loss			
	1st Use	2nd Use	3rd Use
PS x WN	0.29	0.27	0.46
PS x PR	0.031*	0.64	0.001*
PS x U	<0.001*	0.41	0.56
WN x PR	0.14	0.19	<0.001*
WN x U	<0.001*	0.48	0.26
PR x U	0.005*	0.26	0.006*

Figure 1



Flute Deformation			
	1st Use	2nd Use	3rd Use
PS x WN	>0.99	0.31	0.31
PS x PR	0.012*	0.012*	0.006*
PS x U	0.26	0.06	0.006*
WN x PR	0.012*	0.016*	0.008*
WN x U	0.26	0.011*	0.011*
PR x U	0.068	0.38	0.22

Figure 2

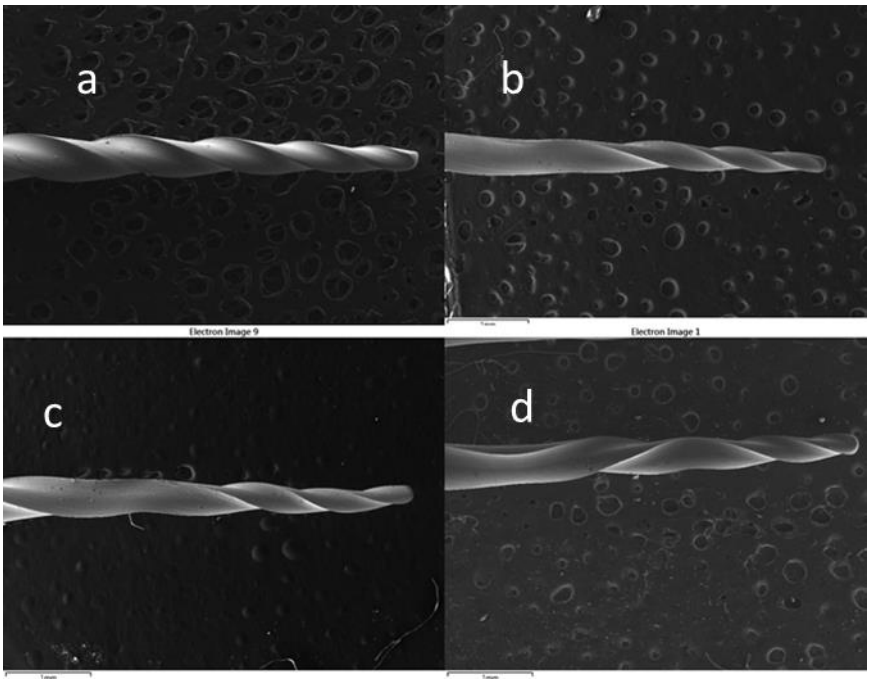


Figure 3

List of tables

Table 1 Instrument sequences followed with Prodesign S, Wizard Navigator, Unicone and Prodesign R systems.

Sequence	Prodesign S	Wizard Navigator	Unicone	Prodesign R
Exploration	Size 10 K-file	Size 10 K-file	Size 10 K-file	Size 10 K-file
Estabilishment of working length	Visual method	Visual method	Visual method	Visual method
First Instrument	Size 30, taper 0.10	Size 10, taper 0.4	Size 25, taper 0.6	Size 25, taper 0.8
Second Instrument	Size 25, taper 0.8	Size 15, taper 0.5	------	------
Third Instrument	Size 25, taper 0.1	Size 20, taper 0.6	------	------
Fourth Instrument	Size 20, taper 0.6	Size 25, taper 0.6	------	------
Fifth Instrument	------	Size 30, taper 0.6	------	------
Sixth Instrument	------	Size 25, taper 0.7	------	------

Table 2 Scores for the instruments conditions according to the instrument's spiral distortion, surface wear and fracture

Score	Flute Deformation	Material Loss	Fracture
1	No unwinding, reverse winding or shortening of spirals along the shaft examined	No wear along the shaft examined	No fracture
2	Unwinding, reverse winding or shortening of only one spiral along the shaft examined	Small amount of wear: one to three areas with defects along the shaft examined	Fracture
3	Unwinding, reverse winding or shortening of more than one spiral along the shaft examined	Moderate wear: four to five areas with defects along the shaft examined	--------
4	----------	Severe wear: more than five areas with defects along the shaft examined	---------

DISCUSSÃO:

A revisão de literatura apresentada contribuiu para a literatura científica por reunir uma grande quantidade de informações dos últimos anos de variados sistemas de movimento oscilatório e contínuo. Diante da grande diversidade de instrumentos disponíveis no mercado, ao abordar variados aspectos da prática clínica, torna-se um excelente material de apoio para facilitar a tomada de decisão dos especialistas.

De acordo com o artigo 1 foi possível perceber que os instrumentos rotatórios reciprocantes apresentam capacidades semelhantes aos instrumentos de rotação contínua no que se refere à capacidade de limpeza e modelagem do sistema de canais radiculares. Porém apresenta maior resistência à fadiga cíclica devido à cinemática deste movimento[5] menor tempo no preparo químico-mecânico além de serem mais baratos por apresentarem-se como instrumentos únicos[6]. Estas vantagens têm contribuído para o uso crescente na prática clínica entre os especialistas e possivelmente poderá substituir os sistemas de movimentos contínuos. Como se trata de uma proposta relativamente nova, introduzida em 2008 por Yared[7], observa-se até o presente momento uma escassez de estudos que relatem o sucesso em longo prazo.

Independente do tipo de movimento empregado durante a instrumentação do canal radicular, a segurança ainda é um dos fatores mais determinante para a escolha do sistema a ser utilizado. Fraturas dos instrumentos de NiTi inesperadas podem ocorrer a qualquer momento, sem que nenhuma deformação prévia seja detectável aos olhos humanos. Portanto, metodologias que envolvam a avaliação das superfícies dos instrumentos após a utilização são de grande valia para tentar estabelecer uma média de usos que um instrumento pode ser utilizado com segurança. Apesar do artigo de revisão de literatura ter abrangido a maioria dos estudos publicados recentemente, utilizando variados sistemas reciprocantes e contínuos, não foi encontrada nenhuma publicação contemplando os instrumentos Unicone, Prodesign e WizardNavigator, por se tratar de sistemas relativamente novos no mercado. Uma vez detectada a carência de pesquisas com estes sistemas, o estudo experimental (artigo 2) foi realizado para fornecer as primeiras informações do comportamento da estrutura destes instrumentos após os três primeiros usos, fornecendo assim as primeiras impressões destes materiais que já encontram-se disponíveis no mercado, e vêm sendo amplamente utilizados pelos profissionais.

No estudo de Varela-Plotino et al[8], a incidência de fratura de instrumentos em blocos de resina foi significativamente mais baixa para os instrumentos reciprocantes do que os de rotação contínua, com média de 10 usos para os reciprocantes comparado com cinco usos para os de movimento contínuo. Neste estudo os instrumentos foram utilizados três vezes e observou-se a ocorrência de fraturas tanto nos sistemas contínuos quanto nos reciprocantes. Embora não exista um consenso a respeito de quantas vezes um instrumento de NiTi pode ser usado com segurança, sempre que alguma deformação plástica for detectada, o descarte deve acontecer para evitar fratura do instrumento[9]. A falha dos instrumentos é influenciada muito mais pela técnica, pela força apicalempregada durante o preparo do que pelo número de usos[10].

A vida útil de um instrumento é diretamente proporcional ao estresse acumulado durante o preparo do canal. Instrumentos flexíveis geralmente apresentam alta resistência à flexão e pouca resistência à torção. Instrumentos mais rígidos apresentam boa resistência à torção e pouca resistência à flexão[11]. No presente estudo a ocorrência de fratura por flexão do instrumento do sistema *WizardNavigator*, mais rígido, ocorreu na curvatura do canal simulado durante o primeiro uso, sem haver, no entanto, nenhuma distorção das espiras. Em contrapartida, os instrumentos da *Prodesign (tip*25*/taper*08*)*, por receberem tratamento térmico no processo de fabricação, portanto altamente flexíveis, embora não tenham fraturado no presente ensaio, apresentaram os maiores scores de distorção das espiras, caracterizando assim a baixa resistência à torção. Braga et al.[12]ao compararem instrumentos de NiTi com tratamento térmico aos instrumentos de fabricação convencional e concluíram que os instrumentos termicamente tratados são aproximadamente 390% mais resistentes à fadiga cíclica.

Outros trabalhos avaliaram a ocorrência de fraturas e deformações de instrumentos [13,14,15,16,17]. No entanto, as diversas metodologias encontradas e a ausência de relatos com os sistemas apresentados neste experimento, inviabilizam uma comparação precisa dos resultados obtidos. A padronização dos métodos de análise de superfície dos instrumentos seria de grande contribuição, para que resultados experimentais possam agregar informações mais precisas e auxiliar na tomada de decisões dos especialistas quanto ao tipo de instrumento a ser usado, bem como o número de usos, fornecendo assim maior segurança.

É de especular, pelos achados neste estudo e na literatura visitada, que há espaço para os sistemas de reciprocidade de rotação no preparo do canal radicular. Ainda falta saber quais são os meios mais seguros e que manobras podem ser adicionadas para melhorar estes sistemas. Ainda, saber de que maneira as outras importantes etapas são afetadas ou podem interferir no desfecho do preparo do canal radicular. Claro está que há muito para ser proporcionado pelos estudos neste importante campo de investigação.

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Anexo 1:

Dra. Flavia Villela <flaviavillela@gmail.com>

yoursubmission

Editorial Team Odontociencia<editorial.team.odontociencia@pucrs.br> 29 de maio de 2015 18:51

Para: "flaviavillela@gmail.com" <flaviavillela@gmail.com>

Dear Flavia Villela Laurindo,

Thank you for submitting your article entitled **Reciprocating versus Rotary instruments: A review.** We are currently reviewing the editorial process, but we are again receiving papers for consideration for publication at RevistaOdontoCiencia. I hope you are patient enough to wait until we get settled and proceed with the reviewing process. You will hear from us soon.

Best wishes,

The editorial Team

RevistaOdontoCiencia

Anexo 2:

Gmail by Google

Dra. Flavia Villela <flaviavillela@gmail.com>

Your recent submission to JOE

1 mensagem

The Journal of Endodontics <support@elsevier.com> 29 de maio de 2015 18:25

Para: flaviavillela@gmail.com

Dear Dr. Flavia Laurindo,

You have been listed as a Co-Author of the following submission:

Journal: Journal of Endodontics
Corresponding Author: Jose Antonio Poli de Figueiredo
Co-Authors: Flavia V Laurindo, BDS, MSc;
Title: Reciprocating and Rotary NiTi instruments: SEM analysis of defect progression following uses

If you did not co-author this submission, please contact the Corresponding Author of this submission at jose.figueiredo@pucrs.br; do not follow the link below.

An Open Researcher and Contributor ID (ORCID) is a unique digital identifier to which you can link your published articles and other professional activities, providing a single record of all your research.

We would like to invite you to link your ORCID ID to this submission. If the submission is accepted, your ORCID ID will be linked to the final published article and transferred to CrossRef. Your ORCID account will also be updated.

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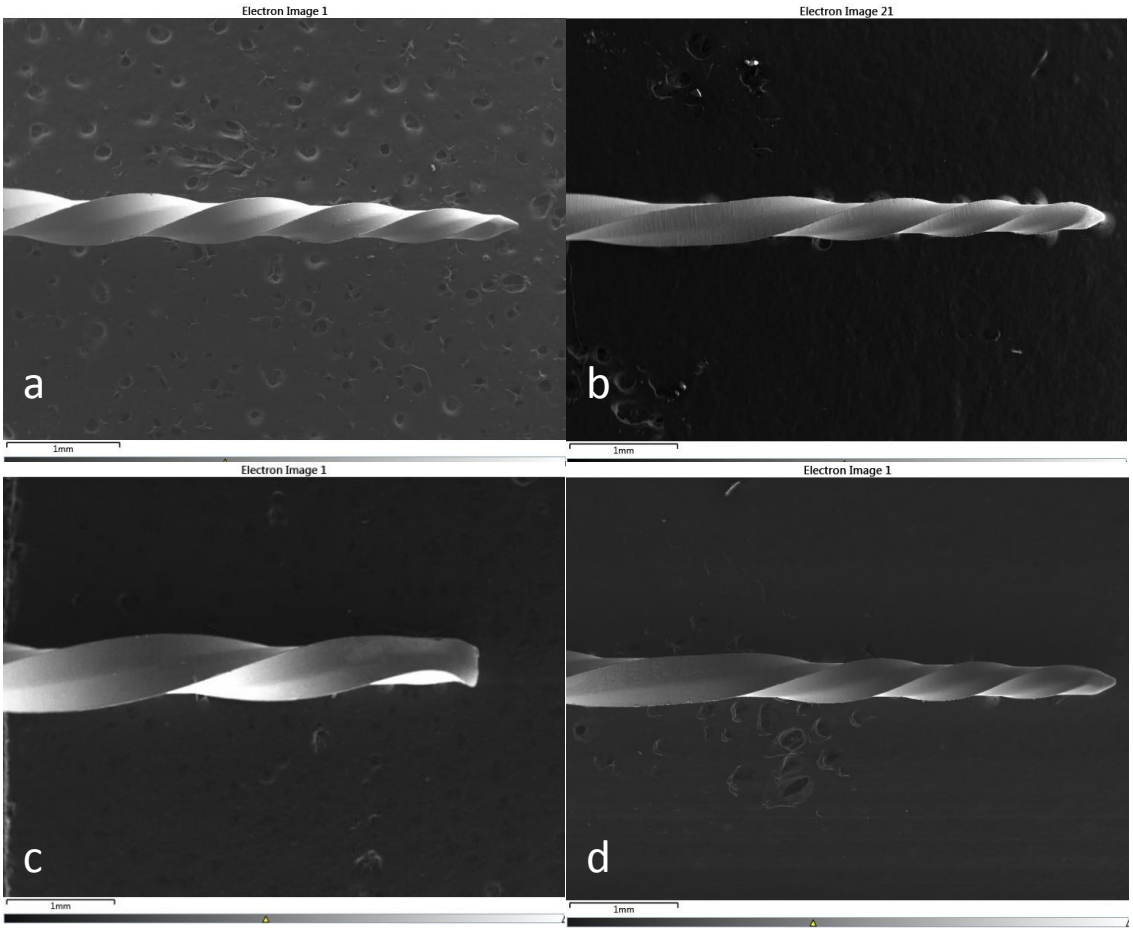
Like other Publishers, Elsevier supports ORCID - an open, non-profit, community based effort - and has adapted its submission system to enable authors and co-authors to connect their submissions to their unique ORCID IDs.
Thank you,
Journal of Endodontics

Anexo 3:

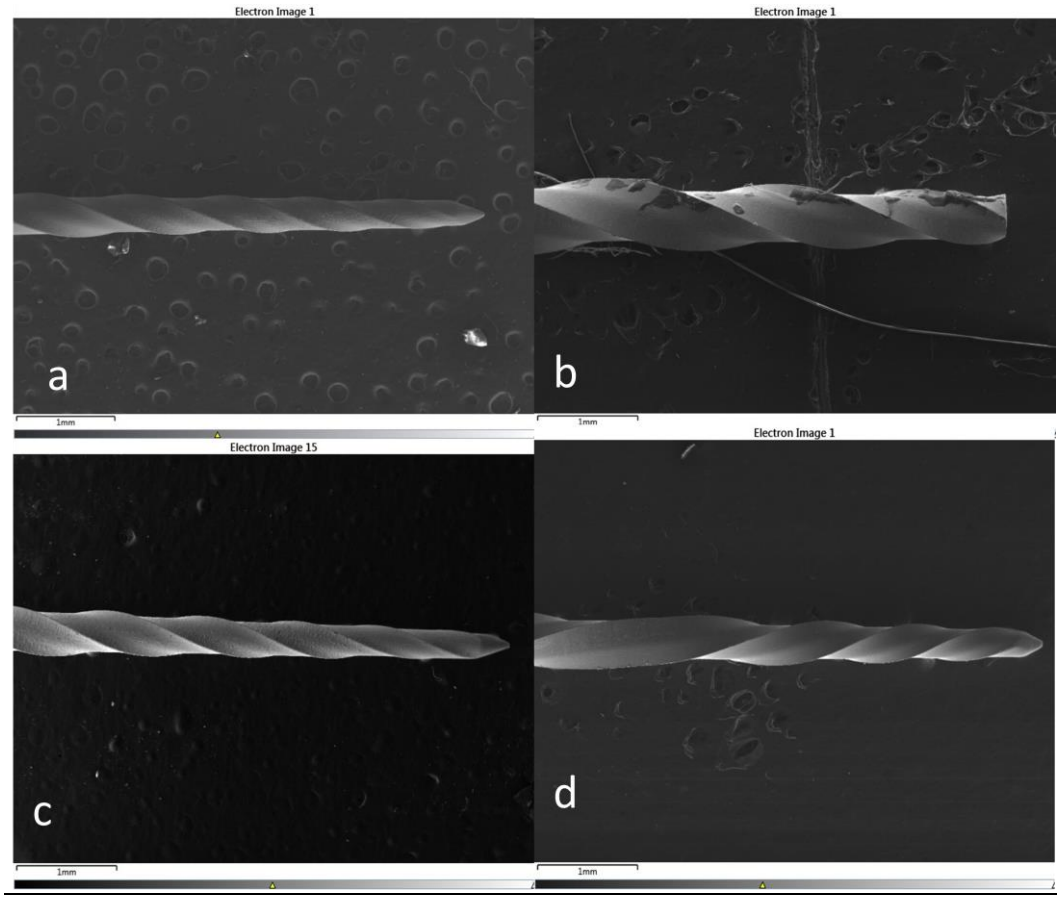
Sistema Unicone



Sequência de imagens obtidas antes e após cada uso dos instrumentos reciprocantes UNICONE. MEV – 75X a:antes do primeiro uso; b: primeiro uso; c: segundo uso; d: terceiro uso.

Anexo 4:

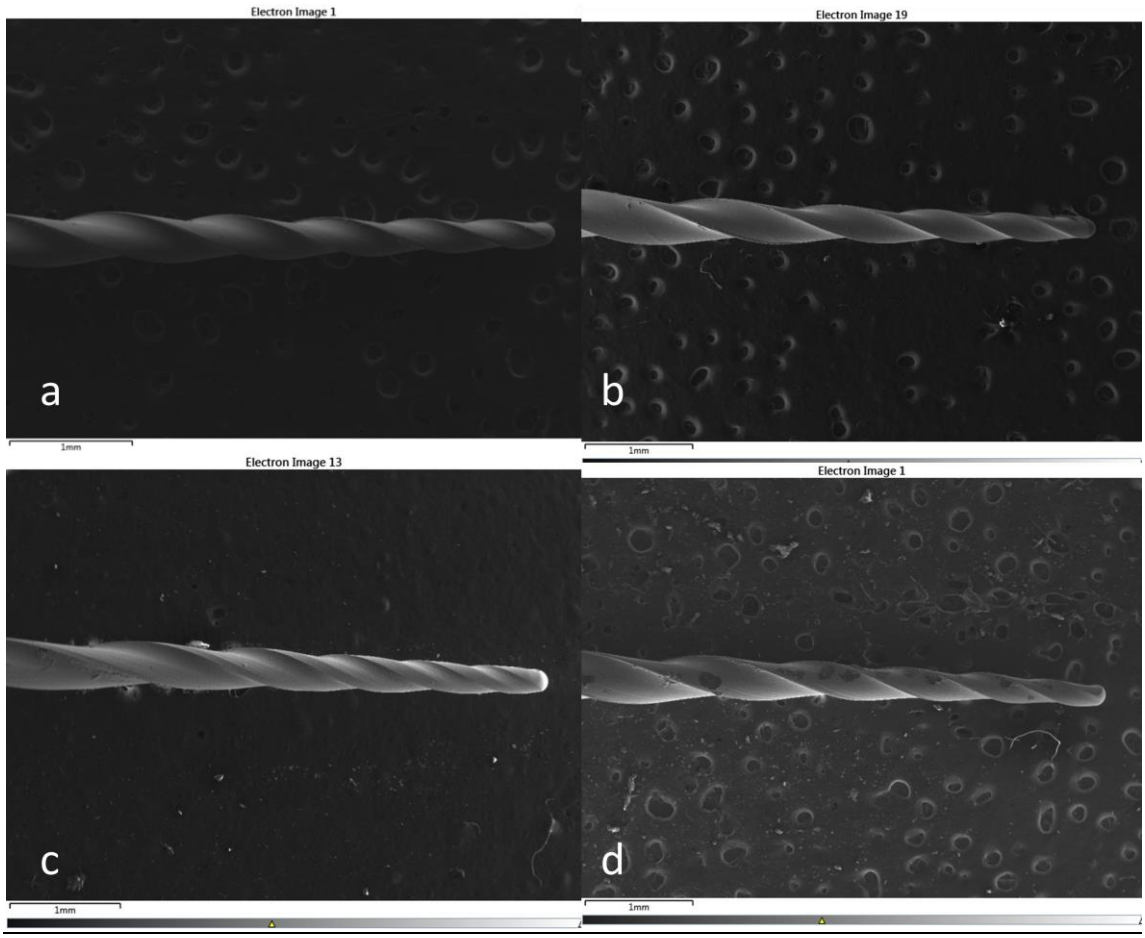
Wizard Navigator (25/06)



Sequência de imagens obtidas antes e após cada uso dos instrumentos de rotação contínua WIZARD NAVIGATOR (25/06). MEV – 75X a: antes do primeiro uso; b: primeiro uso; c: segundo uso; d: terceiro uso.

Anexo 5:

Prodesign S (20/06)



Sequência de imagens obtidas antes e após cada uso dos instrumentos de rotação contínua PRODESIGN S (20/06). MEV – 75X a: antes do primeiro uso; b: primeiro uso; c: segundo uso; d: terceiro uso.