CASE REPORT

Oral Sciences

ROOT CANAL PREPARATION USING A MANUAL OPTION OF INSTRUMENTS MANUFACTURED WITH CONTROLLED MEMORY NiTi TECHNOLOGY: PRELIMINARY OBSERVATIONS

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ABSTRACT: Controlled memory (CM) NiTi instruments have been manufactured using a special thermomechanical process that controls the memory of the material, making the instruments extremely flexible but without the shape memory of conventional superelastic NiTi instruments. An instrument with greater flexibility may cause fewer undesirable changes in the shape of curved root canals, present particularly to the posterior teeth. The aim of this report was to describe a novel manual option of CM NiTi instruments recommended for endodontic treatment of posterior teeth. In this novel hand-operated technique, a size #10 hand ISO stainless steel K-file is used to negotiated the coronal 2/3 of the root canal. After enlarging the coronal portion of the canal with #25/.06 (CM NiTi) manual instrument, the working length (WL) is determined with a size #10 K-file. Then, the root canal preparation is completed with #25/.01 (conventional NiTi), #15/.05 (CM NiTi), and #25/.06 (CM NiTi) instruments, in that order to WL, using hand-operated rotary movement. In larger canals, the use of additional stainless steel hand files may be required to complete the apical enlargement. This sequence of instruments, recently launched on the market by Easy, received the name of "ProDesign M" system and it was proposed to meet a demand for endodontic treatment of posterior teeth in undergraduate dental school clinics, mainly in institutions where there are no available motors for the use of engine-driven CM NiTi rotary instruments. The advantages of this manual technique include a reduced number of stainless steel instruments for preparation, which, combined with the greater flexibility of the CM NiTi instruments, may lead to less risk of ledging, transportation, or perforation during educational practice in undergraduate dental programmes.

KEYWORDS – ProDesign M, CM NiTi, hand-operated instrument, root canal, preparation.

Introduction

Since 1988, when Walia et al. (1) used Nitinol nickel-titanium orthodontic wire alloy for the fabrication of endodontic files, nickel-titanium (NiTi) based superelasticity and shape memory metal alloy (conventional NiTi) is broadly defined in endodontic literature as the alloy that allowed the development of engine-driven rotary instruments and revolutionized mechanical instrumentation techniques with consistent root canal shape, good centring, less debris extrusion and

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faster preparation time (2,3,4).

Despite progress in NiTi rotary shaping instruments, the main concern of clinicians in engine-driven instrumentation use is instrument fracture (5,6). Torsional fracture and cyclic fatigue failure are the main causes of instrument separation. Torsional fracture occurs when an instrument tip or another part of the instrument is locked in the root canal while the shank continues to rotate. When the elastic limit of the metal alloy is exceeded by the torque exerted by the handpiece-driven, fracture of the tip becomes inevitable (7). Cyclic fatigue failure is reported to occur unexpectedly without any sign of previous permanent deformation. This occurs due to the alternating tension/compression cycles that instruments are subjected to when flexed in the region of maximum curvature of the root canal (8). Torque control motors have contributed to reduce the number of instrument separations due to torsional fracture. However, material fatigue of instruments as their diameters increase is still a problem especially in canals with low “radius of curvature”. In addition, the number of rotations to breakage or cyclic fatigue failure will be reached sooner if the instrument is rotating too quickly (9).

With an effort to reduce the effects of these problems, in 2004, Dentsply Maillefer (Ballaigues, Switzerland) launched on the market a manual option of hand-operated NiTi rotary instruments, ProTaper Nickel-Titanium “Hand” files. Dentsply Maillefer aimed at existing users of NiTi rotary as well as those who have either avoided NiTi rotary use or found the outlay too prohibitive, but still appreciate and want the benefits that NiTi rotary instrumentation has to offer (9). However, the occurrence of fractures was similar rate (14%) for both, ProTaper conventional NiTi hand-operated and engine-driven instruments (10). In 2000, Dr. Steve Buchanan (11) had already developed the Greater Taper (GT) system, also available in both engine-driven and hand-operated NiTi rotary instruments.

The mechanical behavior of NiTi alloy is determined by the relative proportions and characteristics of its 3 microstructural phases (ie, austenite, martensite, and R-phase). Thermal processing is one of the most fundamental approaches toward adjusting the transition temperatures of conventional NiTi alloys (12,13,14), bringing beneficial changes in mechanical properties, increasing the fatigue resistance, and improved clinical performance of NiTi rotary endodontic instruments. In recent years, several novel thermomechanical processing and manufacturing technologies have been developed to optimize the microstructure of NiTi wire blanks for rotary instruments. Enhancements in these areas of material management have led to the development of the next-generation endodontic instruments, as martensite wire (M-Wire - Dentsply Tulsa Dental Specialties), R-phase (SybronEndo), and controlled memory wire (CM Wire - DS Dental, Johnson City, TN) (15).

Advances in using NiTi rotary technology are experiencing increase in studies’ rate preparation with NiTi engine-driven instruments superior in comparison with the stainless steel step-back manual techniques even when used by undergraduate students (16,17,18,19,20), and that more universities adopt and incorporate mechanical instrumentation as part of the endodontic curriculum (16,21).

CM NiTi technology represents the latest generation of NiTi rotary instruments (23). The instruments manufactured using CM Wire do not rebound (24) to original shape like conventional NiTi instruments, which, combined with greater flexibility (25), may lead to lower risk of ledging, transportation, or perforation (23) mainly in curved canals or multiple canals of posterior teeth, making these CM NiTi rotary instruments even more suitable for undergraduate dental education practice.

However, despite these advances, the use of NiTi engine-driven instruments is not yet a reality in many universities around the world, especially in developing countries, such as Brazil, since the use of this type of instrument requires the acquisition of electric or air-driven endo motors, either by University or by students. Thus, the purpose of this report was to describe a novel manual option of CM NiTi instruments recommended for endodontic treatment of posterior teeth in undergraduate dental school clinics, mainly in universities where there are no available endo motors for the use of engine-driven CM NiTi rotary instruments. This novel technique will reduce the number of stailess steel instruments required for manual root canal preparation, simplify the armamentarium for undergraduate students, improve the predictability of endodontic treatments of posterior teeth and would require less initial investment compared with NiTi mechanical instrumentation techniques.

Report

The bet on novel CM NiTi manual instruments

On March 17 and 18, 2016, participating in the 8th Easy Training for Professors, promoted by the “Instituto Henrique Bassi” (IHB), in Belo Horizonte, MG, Brazil, we had the opportunity to test the new generation of ProDesign S and ProDesign Logic mechanical rotary systems (Easy Equipamentos Odontologicos, Belo Horizonte, Brazil), both manufactured using CM NiTi technology. ProDesign S system consists of four rotary CM NiTi instruments: #30/.10, #25/.08, #25/.01, #25/.06 (Easy, 2016). ProDesign Logic rotary CM NiTi instruments are available in the following different tip and taper sizes: #15/.03, #15/.05, #25/.01, #25/.03, #25/.05, #30/.01, #30/.03, #30/.05, #35/.01, #35/.03, #35/.05, #40/.01, #40/.03, #40/.05, #45/.01, #50/.01, #25/.04, #25/.06 (Easy, 2016). These NiTi-base instruments feature a modified S-shaped cross-section with two, three or four cutting blades (26,27).

After using these two CM NiTi mechanical rotary systems on hands-on training workshops, we presented to Easy product development team, three root canals of a mandibular second molar prepared with ProDesign S CM NiTi system, but in that case, root canals were completely instrumented using rotary hand-operated movement. We then discussed the possibilities of betting on CM NiTi manual instruments for undergraduate dental education, mainly focusing on institutions where there are no endo motors available for the engine-driven use of rotary CM NiTi instruments.

ProDesign M: a rotary CM NiTi system for hand use

A rotary CM NiTi system for hand use, indicated for endodontic treatment of posterior teeth, consisting of 3 prototype instruments, was then proposed by Easy. The instruments that made up the prototype ProDesign system for hand use were selected from the rotary mechanical instruments of ProDesign family, as ProDesign S and ProDesign Logic systems. The instruments selected were: #25/.01 ProDesing S conventional NiTi instrument, #15/.05 ProDesign Logic CM NiTi instrument, and #25/.06 ProDesing S CM NiTi instrument. The manual handle of the instrument is made of metal and has been designed in a hexagonal shape to allow the most precise hand operation for rotary movement. This prototype manual ProDesign system were then named "Prodesign M" (Easy Equipamentos Odontologicos, Belo Horizonte, Brazil).

Technique description for endodontic treatment of posterior teeth

The technique is crown-down and intuitive. It involves the use of only one size #10 hand ISO stainless steel K-file, one ProDesign conventional Ni-Ti rotary instrument for hand use and two ProDesign CM Ni-Ti rotary instruments for hand use (Easy Equipamentos Odontologicos, Belo Horizonte, Brazil) (Fig. 1).

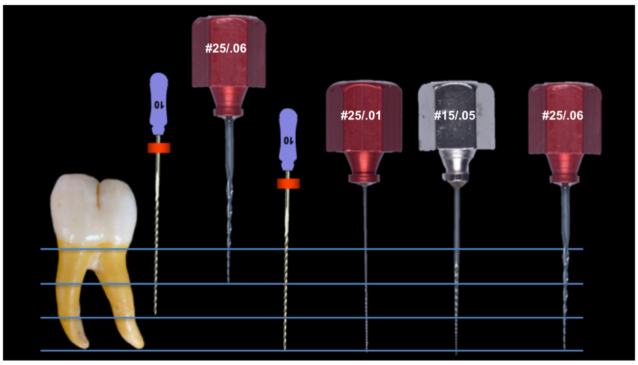

Fig. 1 - The ProDesign M technique: this chart summarizes the ProDesign M working sequence

Initial canal negotiation

The coronal 2/3 of the root canal is negotiated with a stainless steel size #10 hand ISO stainless steel K-file. This step is accomplished with the continuous intracanal use of a antimicrobial agent like 2% chlorhexidine gel, for flood, and 0.12% chlorhexidine solution for irrigation.

Root canal preparation

The coronal portion of the root canal is enlarged with #25/.06 ProDesign M (CM NiTi) manual instrument. The #25/.06 ProDesign M (CM NiTi) instrument is used in the root canal with a slow hand-operated rotary movement and an extremely light apical pressure until resistance is encountered (i.e. until more pressure is needed to make the #25/.06 ProDesign M advance further in the canal). The manual instrument is then pulled out of the canal, cleaned with a gauze to remove the debris filling the flutes, and reinserted and employed in the same manner. Clockwise (CW) and counterclockwise (CCW) movement can be used when resistance has been encountered, but the instrument must be inserted and pulled out of the canal using hand-operated rotary CW movement. This step is repeated until the #25/.06 ProDesign M reaches the coronal 2/3 of the root canal (cervical preflaring) (Fig 2). The working length (WL) is determined, as indicated by an apex locator, with a size #10 K-file. A trial file radiograph can then be exposed.

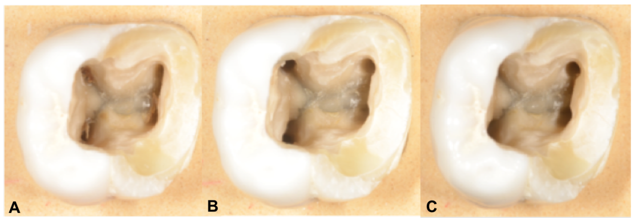

Fig. 2 – Cervical preflaring of mandibular molar root canal entrances promoted by #25/.06 ProDesign M CM NiTi instrument: A) Before cervical preflaring, B) View of mesial root canal entrances - after cervical preflaring, C) View of distal root canal entrances - after cervical preflaring.

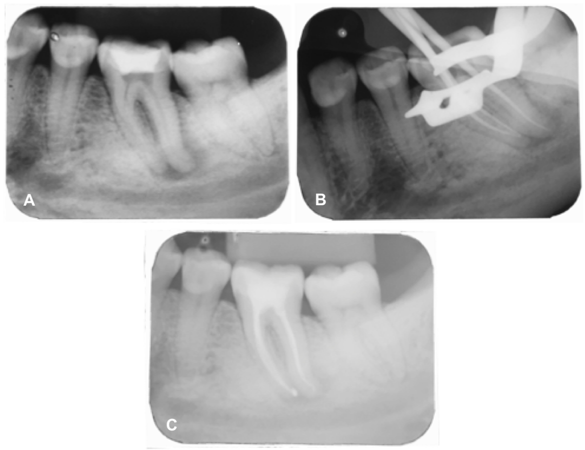

Fig. 3 – Root canal treatment on tooth 36; the canals were prepared with ProDesign M system: A) Initial radiograph, B) Master cone radiograph, C) Post obturation radiograph.

This step is repeated by each one of the instruments of manual ProDesign M system, in that order to WL, according to the following sequence: #25/.01 conventional NiTi instrument (manual pathfinding instrument), #15/.05

CM NiTi instrument, and #25/.06 CM NiTi instrument (Fig 3). In larger canals, the use of additional stainless steel hand files may be required to complete the apical enlargement. The canal preparation is accomplished with continuous canal irrigation using a 2% chlorhexidine gel, 0.12% chlorhexidine solution and a final rinse with EDTA 17% followed by chlorhexidine solution.

Thus, in May 2016, after a period of testing and feasibility analysis, Easy launched "ProDesign M" manual system, a rotary CM NiTi system for hand use, indicated for endodontic treatment of posterior teeth.

Discussion

The introduction of NiTi instruments into Endodontics was a major breakthrough brought about because of its unique property of superelasticity, making NiTi instruments more flexible and resistant to torsional fracture when compared with stainless stell (1). These characteristics of the NiTi alloy stimulated industry to produce instruments with significant changes in the configuration of the active part, variations in the helical angle and cut angle, different increases in taper, and multiple tapers within the same instrument, no longer following the ISO standards published in 1958 for manual instruments (28). Thus, most NiTi rotary engine-driven and hand-operated instruments are shaped with a taper greater than the 0.02-mm taper stainless steel hand files that have been traditionally used for canal instrumentation. The taper of these NiTi rotary instruments varies from 0.04 to 0.12 mm. Root canal instrumentation with these NiTi tapered instruments may result in a significant divergence of the canals from apical to coronal portions (29). The power of the variably tapered instrument concept is in its total control of the root canal shape, from orifice to terminus. For the first time in endodontics since the single-cone era, dentists can predictably create a predefined specific shape throughout the full length of a root canal (11).

Dr. Steve Buchanan (11) reported that when he was an undergraduate dental student, he was taught the advantages of tapered root canal preparations and how to create them with serial step-back shaping routines using traditional K-files and Gates Glidden burs. He further stated that what he did not fully take into acount was the challenge of teaching a manual technique with 63 steps and 18 stainless stell instruments. In addition, for him, the stainless stell hand root canal shaping procedures were complex because the use of relatively nontapered instruments to create tapered root canal shapes.

The special thermomechanical process used to manufacture CM NiTi instruments makes the new generation of instruments extremely flexible but without the shape memory of other NiTi instruments, as opposed to what is found with conventional superelastic forms of NiTi (30).

The technique described in this report involves a manual crown-down technique with 6 steps and use of 4 instruments: one ISO stainless steel file, one conventional Ni-Ti rotary instrument and two CM Ni-Ti rotary instruments, all of them for hand use.

After the negotiation of coronal 2/3 of the root canal with a #10 K-file, #25/.06 ProDesign M CM NiTi instrument is used to promote preflaring of canal. Preflaring of the cervical and middle thirds of the root canal and elimination of interferences in these regions allow for a more accurate assessment of the real anatomical diameter of the apical constriction and more reliable determination of the initial apical file (31,32).

The #25/.06 ProDesign M CM NiTi instrument is able to cut dentine in both directions, CW and CCW, but the instrument must be inserted and pulled out of the canal using hand-operated rotary CW movement. The hand-operated rotary CW and CCW movement (33) can be used, especially when the instrument encounters resistance into root canal. In the present technique, the instrument will frequently engage dentine at its active part, the CCW rotation will immediately disengage the instrument. Theoretically, the hand-operated rotary CW and CCW movement would reduce the incidence of torsional fracture by taper-lock.

In the standard Ni-Ti techniques using rotary engine-driven, it is crucial to enlarge the canal to at least a size 15 file prior to the use of rotary instruments (34,35,36). If not, although the instrument would still advance in the canal, it would bind in dentine; instrument fracture may then occur due to taper-lock. In the present manual technique, the size #10 hand file and #25/.01 hand-operated conventional NiTi instrument ensure the presence of a patent glide path. The impression was that, after cervical preflaring of the root canal with #25/.06 ProDesign M CM NiTi instrument, further enlargement with stainless stell hand files may not be necessary as long as a glide path, with size #10 hand file and #25/.01 hand-operated conventional NiTi instrument, had been established.

ProDesign 25 tip size instrument is a non-tapered instrument with a modified square cross-sectional design which plays the role of pathfinding instrument into rotary engine-driven instruments of ProDesign systems (37). In Endodontics, glide path preparation has been defined as a series of clinical procedural steps that aim to expand or preshape the root canal from its orifice to its foraminal constriction before using greater tip diameter and tapered shaping instruments (38).

After endodontic glidepath, the #15/.05 ProDesign M CM NiTi instrument was used to prepare the root canal until it reached the WL. In order to avoid material fatigue of instruments, preparation was initiated with a smaller tip and taper instrument to facilitate the pathway for the next instrument and minimize the incidence of procedural errors, which would have its tip working freely inside the canal, acting just as a guide. The 0.05-mm taper of ProDesign M 15 tip size instrument allowed the preparation of the middle third of the root canal. Then the #25/.06 ProDesign M CM NiTi instrument is used again to enlarge the canal until it reaches WL. The preparation of the apical part would then be completed with hand files.

Instruments made from CM Wire were nearly 300% - 800% more resistant to fatigue failure than instruments made from conventional NiTi wire with the same design in a dry condition in a 3-point bending device (39). This fatigue resistance superior of CM Wire instruments, when compared to that of instruments made from conventional NiTi alloy, associated with handling rotary NiTi instruments, may favor undergraduate dental education practice once the student will have the opportunity to learn the hand-operated rotary movement using a CM NiTi system as an initial phase before learning the principles and fundamentals of engine-driven rotary NiTi instrumentation. This can increase productivity and improve undergraduate students' learning curve, making them able to treat endodontically posterior teeth safely and predictably even without having an endo motor.

Conclusion

A novel manual option of CM NiTi instruments recommended for endodontic treatment of posterior teeth in undergraduate dental school clinics, mainly in universities where there are no available endo motors for the use of engine-driven CM NiTi rotary instruments, is described. This technique would offer two major advantages: (i) to reduce the number of stailess steel instruments required for manual root canal preparation, simplify the armamentarium for undergraduate students, (ii) to improve the predictability of endodontic treatments of posterior teeth, and (iii) it would require less initial investment compared with NiTi mechanical instrumentation techniques.

The preliminary experience with this manual technique and the first impression were encouraging. However, the need of proper laboratory and clinical evaluation of several parameters (working time in undergraduate dental education practice, apical extrusion of debris, incidence of instrument fracture, canal transportation, etc.) would be essential.

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Resumo

CARVALHO-JUNIOR, Jacy Ribeiro de; OLIVEIRA, Laudimar Alves de. **Preparo do canal radicular usando uma opção manual de instrumentos fabricados por meio da tecnologia do NiTi com memória de forma controlada: observações preliminares.** Oral Sci., jan/dez. 2016, vol. 8, nº 1, p. 22-27.

Os instrumentos de NiTi com memória de forma controlada (CM) são fabricados por meio de um processo termomecânico especial que controla a memória do material, tornando os instrumentos extremamente flexíveis, mas sem a memória de forma dos instrumentos em NiTi superelásticos convencionais. Um instrumento com maior flexibilidade pode provocar menos alterações indesejáveis na forma final do preparo de canais curvos, presentes particularmente em dentes posteriores. O objetivo desse trabalho foi descrever uma nova opção de instrumentos manuais em NiTi CM, recomendada para o tratamento endodôntico de dentes posteriores. Nesta nova técnica manual rotatória, uma lima tipo K de aço inoxidável ISO Nº 10 é usada para negociar os 2/3 cervicais do canal radicular. Após ampliar a porção cervical do canal com o instrumento manual Nº 25/0,06 (NiTi CM), o comprimento de trabalho (CT) é determinado com uma lima tipo K Nº 10. Em seguida, o preparo do canal radicular é realizado com os instrumentos Nº 25/0,01 (NiTi convencional), Nº 15/0,05 (NiTi CM) e Nº 25/0,06 (NiTi CM), nessa ordem, no CT, usando o movimento rotatório manual. Em canais amplos, o uso de limas manuais adicionais de aço inoxidável pode ser necessário para completar o alargamento apical. Essa sequência de instrumentos, recentemente lançados pela Easy, recebeu o nome de sistema "ProDesign M" e foi proposta para suprir uma demanda de tratamento endodôntico de dentes posteriores nas clínicas de graduação em Odontologia, principalmente em instituições onde não há motores disponíveis para o uso mecanizado de instrumentos rotatórios de NiTi CM. As vantagens dessa técnica manual incluem um número reduzido de instrumentos de aço inoxidável para o preparo, que, combinados com a maior flexibilidade dos instrumentos de NiTi CM, podem levar a menor risco de formação de degrau, transporte apical ou perfuração durante as atividades práticas de graduação em Odontologia.

PALAVRAS-CHAVE: ProDesign M, NiTi CM, instrumento manual, canal radicular, preparo.

References

1. Walia HM, Brantley WA, Gerstein H. An initial investigation of the bending and torsional properties of Nitinol root canal files. J Endod 1988;14:346-51.
2. Short JA, Morgan LA, Baumgartner JC. A comparison of canal centring ability of four instrumentation techniques. J Endod 1997;23:503-507.
3. Kosa DA, Marshall G, Baumgartner JC. An analysis of canal centring using mechanical instrumentation techniques. J Endod 1999;25:441-45.
4. Porto Carvalho LA, Bonetti I, Gagliardi Borges MA. A comparison of molar root canal preparation using stainless steel and nickel-titanium instruments. J Endod 1999;25:807-810.
5. Sattapan B, Palamara JEA, Messer HH. Torque during canal instrumentation using rotary nickel-titanium files. J Endod 2000;26:156-160.

6. Sattapan B, Nervo GJ, Palanara JEA, Messer HH. Defects in rotary nickel-titanium files after clinical use. J Endod 2000;26:161-165.

7. Martín B, Zelada G, Varela P, Bahillo JG, Magán F, Ahn S, Rodríguez C. Factors influencing the fracture of nickel-titanium rotary instruments. Int Endod J 2003;36:262-6.

8. Peters OA. Current challenges and concepts in the preparation of root canal systems: A review. J Endod 2004;30:559-67.

9. Webber J. ProTaper for hand use. Aust Endod J 2004;30:80-1.

10. Cheung GS, Bian Z, Shen Y, Peng B, Darvell BW. Comparison of defects in ProTaper hand-operated and engine-driven instruments after clinical use. Int Endod J 2007;40:169-78.

11. Buchanan LS. The standardized-taper root canal preparation--Part 1. Concepts for variably tapered shaping instruments. Int Endod J 2000;33:516-29.

12. Liu Y, McCormick PG. Thermodynamic analysis of the martensitic transformation in NiTi-II: effect of transformation cycling. Acta Mater 1994;7:2407-13.

13. Frick C, Ortega A, Tyber J, Gall K, Maier HJ, El.M A, Liu Y. Thermal processing of polycrystalline NiTi shape memory alloys. Mater Sci Eng A 2005;405:34-49.

14. Gutmann JL, Gao Y. Alteration in the inherent metallic and surface properties of nickel-titanium root canal instruments to enhance performance, durability and safety: a focused review. Int Endod J 2012;45:113-28.

15. Shen Y, Zhou HM, Zheng YF, Peng B, Haapasalo M. Current challenges and concepts of the thermomechanical treatment of nickel-titanium instruments. J Endod 2013;39:163-72.

16. Peru M, Peru C, Mannocci F, Sherriff M, Buchanan LS, Ford TRP. Hand and nickel-titanium root canal instrumentation performed by dental students: a micro-computed tomographic study. Eur J Dent Educ 2006;10:52-9.

17. Er O, Sagsen B, Maden M, Cinar S, Kahraman Y. Radiographic technical quality of root fillings performed by dental students in Turkey. Int Endod J 2006;39:867-72.

18. Balto H, Al Khalifah SH, Al Mugairin S, Al Deeb M, Al-Madi E. Technical quality of root fillings performedby undergraduate students in Saudi Arabia. Int Endod J 2010;43:292-300.

19. Chen JL, Messer HHA. Comparison of stainless steel hand and rotary nickel-titanium instrumentation using a silicone impression technique. Int Endod J 2003;36:199–207.

20. Sadeghi S. Shaping ability of NiTi rotary versus stainless steel hand instruments in simulated curved canals. Med Oral Patol Oral Cir Bucal 2011;16:e454-8.

21. 21. Hänni S, Schönenberger K, Peters OA, Barbakow F. Teaching an engine-driven preparation technique to undergraduates: initial observations. Int Endod J 2003;36:476-82.

22. Ninan E, Berzins DW. Torsion and bending properties of shape memory and superelastic nickel-titanium rotary instruments. J Endod. 2013;39:101-4.

23. HyFlex CM brochure (2012), Colténe/Whaledent, Inc. Available: at www.coltene.com. Acessed on April 2, 2016.

24. Testarelli L, Plotino G, Al-Sudani D, Vincenzi V, Giansiracusa A, Grande NM, Gambarini G. Bending properties of a new nickel-titanium alloy with a lower percent by weight of nickel. J Endod 2011;37:1293-5.

25. Easy Equipamentos Odontológicos {homepage}. Limas Easy ProDesign S. Available at: http://www.easy.odo.br/limas/limas-easy-prodesign-s/.

26. Easy Equipamentos Odontológicos {homepage}. Limas Easy ProDesign Logic. Available at: http://www.easy.odo.br/limas/limas-easy-prodesign-logic/..

27. Thompson SA. An overview of nickel-titanium alloys used in dentistry. Int Endod J 2000;33:297-310.

28. Pettiette MT, Phillips C, Trope M. Effect of endodontic instrument taper on post retention. J Endod. 2003 Jan;29(1):65-8.

29. CM Wire press release. Johnson City, TN: DS Dental; 2010.

30. Wu MK, Barkis D, Roris A, Wesselink PR. Does the first file to bind correspond to the diameter of the canal in the apical region? Int Endod J 2002;35:264-267.

31. Pécora JD, Capelli A, Guerisoli DMZ, Spanó JCE, Estrela C. Influence of cervical preflaring on the apical file size determination. Int Endod J 2005;38:430-436.

32. Roane JB, Sabala CL, Duncanson MG Jr. The "balanced force" concept for instrumentation of curved canals. J Endod. 1985 May;11(5):203-11.

33. Berutti E, Negro AR, Lendini M, Pasqualini D (2004) Influence of manual preflaring and torque on the failure rate of ProTaper rotary instruments. J Endod 2004;30:228-30.

34. Peters OA, Peters CI, Schonenberger K, Barbakow F. ProTaper rotary root canal preparation: assessment of torque and force in relation to canal anatomy. Int Endod J 2003;36:93-9.

35. Patino PV, Biedma BM, Liebana CR, Cantatore G, Bahillo JG. The influence of a manual glide path on the separation rate of NiTi rotary instruments. J Endod 31;114-6.

36. Gomes NV. Sistemas de instrumentação mecanizada. In: Souza-Filho FJ, ed. Endodontia Passo a Passo: Evidências Clínicas, 1st ed. Rio de Janeiro: Artes Médicas; 2015:152.

37. West JD. The endodontic Glidepath: ‘‘secret to rotary safety.’’ Dent Today 2010;29: 90-3

38. Shen Y, Qian W, Abtin H, et al. Fatigue testing of controlled memory wire nickel-titanium rotary instruments. J Endod 2011;37:997–1001.