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REVIEW ARTICLE

Rotary endodontics in primary teeth – A review



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Abstract Endodontic treatment in primary teeth can be challenging and time consuming, especially during canal preparation, which is considered one of the most important steps in root canal therapy. The conventional instrumentation technique for primary teeth remains the “gold-standard” over hand instrumentation, which makes procedures much more time consuming and adversely affects both clinicians and patients. Recently nickel–titanium (Ni–Ti) rotary files have been developed for use in pediatric endodontics. Using rotary instruments for primary tooth pulpectomies is cost effective and results in fills that are consistently uniform and predictable. This article reviews the use of nickel–titanium rotary files as root canal instrumentation in primary teeth. The pulpectomy technique is described here according to different authors and the advantages and disadvantages of using rotary files are discussed.

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1. Introduction

One of the most important concerns in pediatric dentistry is the loss of necrotic primary molars leading to space loss. Although the morphology of root canals in primary teeth renders endodontic treatment difficult (Schafer et al., 2006a,b), pulpectomies of primary teeth with severe pulpal involvement should be considered as the treatment of choice.

Bacteria play an essential role in the initiation and perpetuation of pulpal and periapical disease (Dantas, 1997). The primary objectives when cleaning and shaping the root canal system is to remove soft and hard bacteria-containing tissue, provide an irrigation path for to the apical third, instilling space for instruments, subsequent obturation, and retaining the integrity of radicular structures (Cohen and Hargreaves, 2006). Thus, success of pulpectomy depends on elimination of irrigation pathway by cleaning and shaping the root canals (Yang et al., 1996).

Root canal preparation is performed with reamers, files, burs, sonic instruments, mechanical apparatuses, and with nickel–titanium (Ni–Ti) rotary file systems. Since most hand preparation techniques are time consuming and can lead to iatrogenic errors (i.e., ledging, zipping canal transportation, and apical blockage), much attention has been directed toward root canal preparation technique with Ni–Ti rotary instruments (Walton and Torabinejad, 2002). Numerous studies have reported that they could efficiently create smooth, predetermined funnel-form shapes with minimal risk of ledging and transportation (Dantas, 1997; Esposito and Cunningham, 1995; Thompson and Dummer, 1997). The design and high flexibility of Ni–Ti files allow instruments to closely follow the original root canal path, especially in curved canals (Esposito and Cunningham, 1995; Gluskin et al., 2001; Hidsmann et al., 2003; Sonntag et al., 2003). However, all these studies were done in permanent teeth.

A practical pulpectomy technique for the primary teeth should include the following (Kuo et al., 2006):

- 1) Fast procedure with short treatment time and minimal number of appointments.
- 2) Effective debridement of the root canal without weakening the tooth structure or endangering the underlining permanent teeth.
- 3) Minimal procedural complications.
- 4) Maintaining tooth function until it is naturally exfoliated.

Negotiation and thorough instrumentation of bizarre and tortuous canals encased in roots programed for physiological resorption are the main challenges for pulpectomy (Ahmed, 2013).

Mechanical preparation of primary teeth utilizing Ni–Ti rotary files was first done by Barr et al. (2000). They concluded that the use of Ni–Ti rotary files for root canal preparation in primary teeth was cost effective, faster, and resulted in consistently uniform and predictable fillings. Several investigators have reported the advantages of preparation with rotary Ni–Ti instruments over the manual method for both experienced and inexperienced operators (Nagaratna et al., 2006; Sleiman et al., 2007). Silva et al. reported that Ni–Ti rotary preparation

for extracted teeth was faster than hand preparation but the canals were not as clean (Silva et al., 2004).

Ni–Ti rotary instruments of different designs are available. Manufacturers highlight their cleaning efficacy for root canal preparations, simple procedures, and decreased procedure times, which is especially important in children. Various designs for taper, blades, grooves, and tips have been suggested (Bergmans et al., 2003). The shaft designs can be grouped according to taper into two categories: progressive or constant. It has been reported that instruments with progressive tapers can shape canals more quickly than constant taper instruments (Veltri et al., 2005). In the progressive Pro-Taper system, the shaping files (S) have an increasing taper in the coronal direction, whereas the finishing files (F) have a decreasing taper. It has been claimed that the increasing taper instruments have enhanced flexibility in the middle region and at the tip, and that the decreasing taper instruments provide a larger taper in the important apical region but make them stiff (Bergmans et al., 2003).

According to authors who initially advocated rotary technique in primary teeth, the pulpectomy technique begins with a standard access and removal of coronal tissue (Barr et al., 1999, 2000). Ni–Ti PROFILE® is chosen according to that which approximates the canal size. It is inserted into the canal while rotating and is taken to working length as determined by pre-treatment radiography. The rotating file is withdrawn and cleaned of pulp tissue and dentinal debris. The canal is cleansed and shaped with sequentially larger files until the last file binds. Apical overextension of Ni–Ti file can result in an enlarged apical foramen and cause an overflow of pulpectomy paste. Sterile water or chlorhexidine can be used to keep the canals moist. Frequently inspecting each file for flute unwinding or distortion is important, and files with these characteristics should be discarded immediately. If no flute distortion is detected, discard the file after using on five primary teeth. After irrigation, the canals are dried and filled with zinc oxide and eugenol using a hand files to push the paste just short of the apex.

Shashikiran et al. also compared the Ni–Ti rotary PROFILE and K files hand instrumentation on root canal preparation of primary and permanent molars for their efficacy in preparation time, instrumentation failure, and shaping the canals. They concluded that PROFILE 0.04 taper 29 series prepared canal rapidly than conventional K files (Shashikiran, 2006).

According to Kuo et al., the clinical procedure is as follows - under appropriate local anesthesia and rubber dam isolation, the pulpectomy begins with complete caries removal, a standard access opening and removal of coronal pulp tissue (Kuo et al., 2006). The shelf of dentin overlying most canal orifice is reduced using a high speed round bur until the entire canal orifice is clearly identified. An approximate working length is derived terminating approximately 1 mm above the root apex. Before instrumentation, the pulp chamber is copiously irrigated with 2.5% sodium hypochlorite. A number 10 k file is first used to explore the canals. Then the ProTaper SX file is inserted into the canal to about 3 mm beyond the root canal orifice with a slight buccolingual brushing motion to remove any remaining overlying dentin and to improve straight line access. The S2 file is then inserted into the canal

while rotating and taken to the working length. Pulp stumps are commonly wrapped around the S2 file when it is withdrawn which is uncommonly found in stainless steel files. Copious irrigation with 2.5% sodium hypochlorite and normal saline is used during each file change. The root canals are then dried with sterile paper points and subsequently filled by injecting a resorbable calcium and iodoform paste. With teeth already undergoing physiological root resorption (less than one third), the greater taper (8–5.5%) and apical size of 25 of the F2 file might be a better choice than S2. A new Ni–Ti rotary instrument with a more appropriate length, taper, and tip size for the primary dentition would be advantageous.

The K3 Endo Ni–Ti rotary file system was introduced in 2002. These files are designed with a wide radial land, which is meant to make the instrument more resistant to torsional and rotary stresses. It also features “radial land relief”, which aids in protecting the file from “over engagement”, in the canal; thus, less instrument separation or distortion should occur. According to Ankrum et al., this file features a variable core diameter designed to increase flexibility, and it has a safe-ended tip to decrease the incidence of ledging, perforation, and zipping (Ankrum et al., 2004). Numerous studies have shown that Ni–Ti rotary instruments can effectively produce a well-tapered root canal form that is sufficient for obturation, with minimal risk of transporting the original canal (Bertrand et al., 2001; Hulsmann et al., 2001; Thompson and Dummer, 1998). Guelzow et al. compared various parameters of root canal preparation using a manual technique and six different rotary Ni–Ti instruments. They concluded that all Ni–Ti systems maintained the canal curvature and were more rapid than a standardized manual technique. ProTaper instruments created more regular canal diameters (Guelzow et al., 2005). According to Barr et al., maintaining the original path of the root canal is essential to ensure the integrity of the germ of the permanent successor (Barr et al., 1999, 2000) Elmsallati et al. showed that K3 Rotary System® produces minimum wear of root canal walls, which is an interesting aspect in the endodontic preparation of primary teeth (Elmsallati et al., 2006). Francinne et al. evaluated apical displacement and time needed for instrumentation of root canals of primary molars by the K3 rotary system and manual K files and found a significantly shorter clinical time for the rotary system.

A new generation of Ni–Ti rotary files appeared with the Mtwo endodontic instruments. The specific design and flexibility of Mtwo instrument maintain the original root canal curvature and these instruments are effective and safe, so cleaning can be completed in less time in permanent teeth (Foschi et al., 2004; Kuzekanani et al., 2009; Malagino et al., 2012; Schafer et al., 2006a,b; Thompson and Dummer, 1997).

Azar et al. compared the cleaning efficacy of manual K files and two rotary systems-Mtwo and ProTaper for root canal preparation in primary molars and concluded that all the three systems showed equally acceptable cleaning ability in primary molar root canals. They modified the sequence of the three ProTaper instruments slightly to prepare the canals. Root canals were cleaned in a crown down method with three instruments in the sequence from S1 in the coronal third of the root canal, S2 in the middle third, and F1 till the working length (Azar et al., 2012). Pinheiro et al. used a hybrid technique for instrumentation of canals in primary molars with the ProTaper system and K-files (DentsplyMaillefer). Root canals were prepared initially by manual instrumentation using a size

15K-file followed by S1 and S2 of the rotary system; then again instrumenting with manual instrumentation with size 15 and 20K-files followed by rotary using a system F1. Finally instrumentation was done with manual instrumentation with size 25K-file and F2 using a rotary system (Pinheiro et al., 2012).

Another new generation files are Flex-Master files, have round passive tips, a modified cross section, convex triangular shape with sharp cutting edges, and no radial lands. They resemble K-file configuration enhancing dentine cutting effectiveness in permanent teeth (Hidsmann et al., 2003; Hubscher et al., 2003; Weiger et al., 2003; Zarrabi et al., 2006). Makarem et al. conducted a randomized controlled clinical trial in the pulpectomy of primary second molar teeth. They achieved superior radiographic findings and less chair time with Flex-Master system (Makarem et al., 2014). Bahrololoomi et al. also suggested the application of the Flex-Master system for preparation of primary root canals during pulpectomy (Bahrololoomi et al., 2007).

Hero 642 system (Schafer, 2001) and its new variant Hero Shaper in which helix angle increases from tip to shank have improved efficiency, flexibility, and strength in root canal treatments of permanent teeth (Veltri et al., 2005). Kummer et al., prepared root canals with the Hero 642 system and a reducing 50:1 handpiece. Preparation was performed with 21 mm nickel titanium instruments with 2% and 4% tapers using the crown down technique. The protocol established for instrumentation comprised a kit with 3 instruments: (1) Hero 642 taper 0.04, size 30, 2 mm short of the working length; (2) Hero 642 taper 0.02, size 35, up to the working length; (3) Hero 642 taper 0.02, size 40, up to the working length. Each Hero instrument was introduced into the canal with a gentle push and pull motion (Kummer et al., 2008).

Musale et al. evaluated the efficacy of rotary PROFILE®, ProTaper, Hero Shaper, and K file in shaping ability, cleaning efficacy, preparation time and instrument distortion in primary molars and concluded that rotary files prepared more conical canals in primary teeth than manual instruments. Reduced preparation time was also noticed (Musale and Mujawar, 2014). According to him application of protocols for permanent teeth to primary teeth may lead to lateral perforation on the inner root surface, especially in curved molar roots. The abrupt cervical constriction, with a shelf of dentin overlying the canal orifice results in an acutely curved root canal orifice in primary molars which should be removed to improve the straight line access and reduce the risk of instrument separation (Musale, 2013). Yang et al. also reported less canal transportation and better centering ability using the Hero Shaper (Yang et al., 1996).

Pro Taper Next has recently been introduced which consists of five files (X1–X5). It is made up of the M-wire Ni–Ti technology that is formed by characteristic thermomechanical processing. The instrument is flexible and there is increased resistance to cyclic fatigue. Hence, there are less chances of instrument separation (Dhingra et al., 2014; Rahman et al., 2014).

Wave-One and Reciproc brands of Ni–Ti instruments adopted the single file system and advocated the reciprocation concept. These files are made of a special Ni–Ti alloy called M-wire that is created by an innovative thermal treatment process. This procedure has been developed using superelastic Ni–Ti wire blanks that contain substantial stable martensite for clinical use. The benefits of M-wire are increased flexibility

of the instruments and resistance to cyclic fatigue (Young–Jun Lim et al., 2013; Plotino et al., 2012). According to Webber, while current teaching advocates the use of multiple Ni–Ti files of different diameters and tapers to gradually enlarge the root canal, only one Wave One single shaping file is required to prepare the canal to an adequate size and taper, even in narrow and curved canals (Webber, 2011).

Katge et al. concluded for their study on primary molar pulpectomy that the reciprocating system (Wave One) and the rotary system (Pro Taper) showed better cleaning efficiency when compared to manual instrumentation especially in the coronal and middle one third of root canals (Katge et al., 2014).

2. Advantages

The design and flexibility of Ni–Ti alloy instruments allow files to preserve the original anatomy of curved canals and reduce procedural errors especially in primary teeth (Kuo et al., 2006; Silva et al., 2004). In addition, because of the funnel-shaped canal preparation, a more predictable uniform paste filling can be obtained in primary teeth.

Rotary files also improve patient cooperation by shortening treatment time for cleaning canals (Crespo et al., 2008). This factor is clinically relevant in pediatric dentistry because it allows faster procedures with maintenance of quality and security as well as reducing patient's and professional's fatigue. Considering that rotary files are more convenient to use, their application may be more appropriate in children with behavior management problems (Finn, 1973; Hulsmann et al., 2003; Sonntag et al., 2003). The irregular canal walls of primary molars are effectively cleaned with Ni–Ti, since the clockwise motion of the rotary files pulls pulpal tissue and dentin out of the canal as the files are engaged. Due to the conical pathway of preparation and effortless entrance of obturatory paste, less overfilling occurs. Ni–Ti files do not require precurvature due to their elastic memory; they are motor activated and can prepare the root canal with high speed (Kosa et al., 1999). The probability of root canal deformation is reduced due to its elastic memory and radial aspect that keeps the file in the center of the root canal via wall support and inactive tips (Coleman et al., 1995). By using rotary files, we can avoid the use of Gates–Glidden drills or round burs to remove the dentin shelf overlying the canal orifice which might cause accidental perforation of the pulpal floor or excessive removal of inner root structure especially when treating primary molars with thinner pulpal floors (Ruddle, 2001).

3. Disadvantages

Primary dentin is softer and less dense than that of the permanent teeth and the roots are shorter, thinner, and more curved. Root tip resorption is often undetectable. The root canal system is characterized by a ribbon shaped root morphology (Finn, 1973). All of these characteristics hinder the application of Ni–Ti rotary instruments in primary teeth. The basic dilemma is that all rotary instruments are centered in root canals during rotation and leave unclean areas and potentially infected tissue in fins and isthmuses (Drukteinis and Balciuniene, 2006; Finn, 1973) of primary teeth. Therefore, in ribbon shaped canals, it is necessary to use an additional

H-file (Nos. 25 or 30) combined with copious sodium hypochlorite irrigation to remove any loose pulp tissue with a brushing motion and to ensure that all the root canals are cleared and ready for filling. The high cost of Ni–Ti rotary systems and need for training to learn the technique are their disadvantages (Kim et al., 2009; Kuo et al., 2006; Schafer et al., 2006a,b). Previous training of the operator in rotary instrumentation is important to control the working length because there is reduction in tactile sensitivity during apical preparation compared with manual mechanical preparation.

4. Summary

The removal of organic debris is the main purpose of pulpectomies in primary teeth. The goal can be achieved with manual or rotary Ni–Ti instruments. Considering that preparation time is an important clinical factor in pediatric patient management, the use of rotary instruments for pulpectomies in primary teeth is recommended.

Conflict of interest

The authors have no conflict of interest to declare.

References

- Ahmed, H., 2013. Anatomical challenges, electronic working length determination and current developments in root canal preparation of primary molar teeth. *Int. Endod. J.* 46, 1011–1022.
- Ankrum, M.T., Hartwell, G.R., Truitt, J.E., 2004. K3 Endo, ProTaper, and ProFile systems: breakage and distortion in severely curved roots of molars. *J. Endod.* 30, 234–237.
- Azar, Muhammed Reza, Safi, Laya, Nikaein, Afshin, 2012. Comparison of the cleaning capacity of MTWO Pro Taper and rotary systems and manual instruments in primary teeth. *Dent. Res. J.* 9, 146–151.
- Bahrololoomi, Tabrizzadeh, M., Salmani, L., 2007. In vitro comparison of instrumentation time and cleaning capacity between rotary and manual preparation techniques in primary teeth. *J. Dent.* 4, 2.
- Barr, E.S., Kleier, D.J., Barr, N.V., 1999. Use of nickel-titanium rotary files for root canal preparation in primary teeth. *Pediatr. Dent.* 21 (7), 453–454, PMID: 10633522.
- Barr, E.S., Kleier, D.J., Barr, N.V., 2000. Use of nickel-titanium rotary files for root canal preparation in primary teeth. *Pediatr. Dent.* 22 (1), 77–78, PMID: 10730297.
- Bergmans, L., Van Cleynenbreugel, J., Beullens, M., Wevers, M., Van Meerbeek, B., Lambrechts, P., 2003. Progressive versus constant tapered shaft design using NiTi rotary instruments. *Int. Endod. J.* 36, 288–295.
- Bertrand, M.F., Lupi-Pegurier, L., Medioni, E., Muller, M., Bolla, M., 2001. Curved molar root canal preparations using Hero 642 rotary nickel-titanium instruments. *Int. Endod. J.* 34, 631–636.
- Cohen, S., Hargreaves, K.M., 2006. *Pathways of the Pulp*, 9th ed. Mosby Publishers, St. Louis, pp. 301–311, 842.
- Coleman, C.L., Svec, T.A., Rieger, M., Wang, M., Suchina, J.A., Glickman, G.N., 1995. Stainless steel vs nickel-titanium K-files: analysis of instrumentation in curved canals. *J. Endod.* 21, 237–242.
- Crespo, S., Cortes, O., Garcia, C., Perez, L., 2008. Comparison between rotary and manual instrumentation in primary teeth. *J. Clin. Pediatr. Dent.* 32, 295–298.
- Dantas, C.J., 1997. Histological evaluation of the effectiveness of five instrumentation techniques for cleaning the apical third of root canals. *J. Endod.* 23, 499–502.

- Dhingra, Anil, Banerjee, Satyabrata, Aggarwal, Neha, Yadav, Vikrant, 2014. Canal shaping with pro taper next: an ex vivo study. *Int. J. Sci. Stud.* 2, 1–4.
- Drukteinis, S., Balciuniene, I., 2006. A scanning electron microscopic study of debris and smear layer remaining following use of AET instruments and K-flexfiles. *Stomatologija* 8, 70–75.
- Elmsallati, E.A., Wadachi, R., Ebrahim, A.K., Suda, H., 2006. Debris retention and wear in three different nickel-titanium rotary instruments. *Aust. Endod. J.* 32, 107–111.
- Espósito, P.T., Cunningham, C.J., 1995. A comparison of canal preparation with nickel-titanium and stainless steel instruments. *J. Endod.* 21, 173–176.
- Finn, S.B., 1973. Morphology of primary teeth. In: Finn, S.B. (Ed.), *Clinical Pedodontics*, 4th ed. Saunders Company, Philadelphia, pp. 59–70.
- Foschi, F., Nucci, C., Montebugnoli, L., Marchionni, S., Breschi, L., Malagnino, V.A., et al, 2004. SEM evaluation of canal wall dentine following use of Mtwo and ProTaper NiTi rotary instruments. *Int. Endod. J.* 37, 832–839.
- Gluskin, A.H., Brown, D.C., Buchanan, L.S., 2001. A reconstructed computerized tomographic comparison of Ni-Ti rotary GT files versus traditional instruments in canals shaped by novice operators. *Int. Endod. J.* 34, 476–484.
- Guelzow, A., Stamm, O., Martus, P., Kielbassa, A.M., 2005. Comparative study of six rotary Ni-Ti system and hand instrumentation for root canal preparation. *Int. Endod. J.* 38, 743–752.
- Hidsmann, M., Gressmann, G., Schafers, F., 2003. A comparative study of root canal preparation using FlexMaster and HERO 642 rotary NiTi instruments. *Int. Endod. J.* 36, 358–366.
- Hubscher, W., Barbakow, F., Peters, O.A., 2003. Root canal preparation with FlexMaster; canal shapes analyzed by micro-computed tomography. *Int. Endod.* 36, 740–747.
- Hulsmann, M., Schade, M., Schafers, F., 2001. A comparative study of root canal preparation with HERO 642 and Quantec SC rotary Ni-Ti instruments. *Int. Endod. J.* 34, 538–546.
- Hulsmann, M., Herbst, U., Schafers, F., 2003. Comparative study of root-canal preparation using Light-speed and Quantec SC rotary NiTi instruments. *Int. Endod. J.* 36, 748–756.
- Katge, F., Patil, D., Poojari, M., Pimpale, J., Shitoot, A., Rusawat, B., 2014. Comparison of instrumentation time and cleaning efficacy of manual instrumentation, rotary systems and reciprocating systems in primary teeth: an vitro study. *J. Indian Soc. Pedod. Prev. Dent.* 32, 311–316.
- Kim, H.C., Kim, H.J., Lee, C.J., Kim, B.M., Park, J.K., Versluis, A., 2009. Mechanical response of nickel-titanium instruments with different cross-sectional designs during shaping of simulated curved canals. *Int. Endod. J.* 42, 593–602.
- Kosa, D.A., Marshall, G., Baumgartner, J.C., 1999. An analysis of canal centering using mechanical instrumentation techniques. *J. Endod.* 25, 441–445.
- Kummer, T.R., Calvo, M.C., Cordeiro, M.M., de Sousa Vieira, R., de Carvalho Rocha, M.J., 2008. Ex vivo study of manual and rotary instrumentation techniques in human primary teeth. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod.* 105, 84–92.
- Kuo, C.I., Wang, Y.L., Chang, H.H., Huang, G.F., Lin, C.P., Guo, M.K., et al, 2006. Application of Ni-Ti rotary files for pulpectomy in primary molars. *J. Dent. Sci.* 1, 10–15.
- Kuzekanani, M., Walsh, L., Yousefi, M.A., 2009. Cleaning and shaping curved root canals: Mtwo vs Pro Taper instruments, a lab comparison. *Indian J. Dent. Res.* 20, 268–270.
- Lim, Young-Jun, Park, Su-Jung, Kim, Hyeon-Cheol, Min, Kyung-San, 2013. Comparison of the centering ability of Wave. One and Reciproc nickel-titanium instruments in stimulated curved canals. *Restor. Dent. Endod.* 38, 21–25.
- Makarem, Abbas, Ravandeh, Navid, Ebrahim, Masoumeh, 2014. Radiographic assessment and chair time of rotary instruments in the pulpectomy of primary second molar teeth: a randomised controlled clinical trial. *J. Dent. Res. Clin. Dent. Prospect.* 8, 84–89.
- Malagino, V.A., Grande, N.M., Plotino, G., Somma, F. The Mtwo NiTi rotary system for root canal preparation. Available from: <www.vdw-dental.com/pdf/presse/RO0306_59-62_Malagino.pdf>. [Last cited on Apr 4, 2012].
- McDonald, R.E., Avery, F.R., 2000. *Dentistry for the Child and Adolescent*, 7th ed. Mosby Publishers, St. Louis, p. 401.
- Musale, P.K., 2013. Rotary instruments in primary teeth. *J. Int. Oral Health* 5, 140.
- Musale, P.K., Mujawar, S.A., 2014. Evaluation of the efficacy of rotary versus hand files in root canal preparation of primary teeth in vitro using CBCT. *Eur. Arch. Paediatr. Dent.* 15, 113–120.
- Nagaratna, P.J., Shashikiran, N.D., Subbareddy, V.V., 2006. In vitro comparison of Ni Ti rotary instruments and stainless steel hand instruments in root canal preparations of primary and permanent molar. *J. Indian Soc. Pedod. Prev. Dent.* 24, 186–191.
- Peters, O.A., Peters, C.I., Schoneberger, K., Barbakov, F., 2003. Pro Taper rotary root canal preparation: effects of canal anatomy on final shape analyzed by micro-CT. *Int. Endod. J.* 36, 86–92.
- Pinheiro, S.L., Araujo, G., Bincelli, I., Cunha, R., Bueno, C., 2012. Evaluation of cleaning capacity and instrumentation time of manual, hybrid and rotary instrumentation techniques in primary molars. *Int. Endod. J.* 45, 379–385.
- Plotino, G., Grande, N.M., Testarelli, L., Gambarini, G., 2012. Cyclic fatigue of Reciproc and WaveOne reciprocating instruments. *Int. Endod. J.* 45, 614–618.
- Rahman, H., Chandra, A., Singh, S., 2014. In vitro evaluation of dentinal microcrack formation during Root canal preparations by different NiTi systems. *Int. J. Res. Dev.* 3, 43–47.
- Ruddle, C.J., 2001. The Pro Taper technique. *Dent Today* 20, 58–68.
- Schafer, E., 2001. Shaping ability of Hero 642 rotary nickel-titanium instruments and stainless steel hand K-Flexfiles in stimulated root canals. *Oral Surg. Oral Med. Oral Pathol. Oral Radiol. Endod.* 92, 215–220.
- Schafer, E., Erler, M., Dammaschke, T., 2006a. Comparative study on the shaping ability and cleaning efficiency of rotary Mtwo instruments. Part a. Shaping ability in simulated curved canals. *Int. Endod. J.* 39, 196–202.
- Schafer, E., Erler, M., Dammaschke, T., 2006b. Comparative study on the shaping ability and cleaning efficiency of rotary Mtwo instruments. Part b. Cleaning effectiveness and shaping ability in severely curved root canals of extracted teeth. *Int. Endod. J.* 39, 203–212.
- Shashikiran, N.D., 2006. In vitro comparison of Ni Ti rotary instruments and stainless steel hand instruments in root canal preparation of primary and permanent molars. *J. Indian Soc. Pedod. Prev. Dent.* 24, 186–191.
- Short, J.A., Morgan, L.A., Baumgartner, J.C., 1997. A comparison of canal centering ability off our instrumentation techniques. *J. Endod.* 23, 503–507.
- Silva, L.A., Leonardo, M.R., Nelson-Filho, P., Tanomaru, J.M., 2004. Comparison of rotary and manual instrumentation techniques on cleaning capacity and instrumentation time in deciduous molars. *J. Dent. Child* 71, 45–47.
- Sleiman, F., Abou-Jaoude, S., Berberi, R., 2007. The use of the K3 orifice openers in primary teeth preparation. *Oral Health* 97, 17–18.
- Sonntag, D., Delschen, S., Stachniss, V., 2003. Root canal shaping with manual and rotary NiTi file performed by students. *Int. Endod. J.* 36, 715–723.
- Thompson, S.A., Dummer, P.M., 1997. Shaping ability of ProFile. 04 Taper Series 29 rotary nickel-titanium instruments in simulated root canals. Part 2. *Int. Endod. J.* 30, 8–15.
- Thompson, S.A., Dummer, P.M.H., 1998. Shaping ability of Quantec Series 2000 rotary nickel-titanium instruments in simulated canals. Part 1 and 2. *Int. Endod. J.* 31, 259–274.
- Veltri, M., Mollo, A., Mantovani, L., Pini, P., Balleri, P., Grandini, S., 2005. A comparative study of Endo flare-Hero Shaper and Mtwo NiTi instruments in the preparation of curved root canals. *Int. Endod. J.* 38, 610–616.

- Walton, R.E., Torabinejad, M., 2002. Principles and Practice of Endodontics, 3rd ed. Saunders Company, p. 222..
- Julian Webber. The Wave One single-file reciprocating system. <www.roottreatmentuk.com>.
- Weiger, R., Bruckner, M., ElAyouti, A., Lost, C., 2003. Preparation of curved root canals with rotary FlexMaster instruments compared to Light speed instruments and NiTi hand files. *Int. Endod. J.* 36, 483–490.
- Yang, S.F., Rivera, E.M., Walton, R.E., Baumgardner, K.R., 1996. Canal debridement: effectiveness of sodium hypochlorite and calcium hydroxide as medicaments. *J. Endod.* 22, 521–525.
- Zarrabi, M.H., Bidar, M., Jafarzadeh, H., 2006. An in vitro comparative study of apically extruded debris resulting from conventional and three rotary (Profile, Race, FlexMaster) instrumentation techniques. *J. Oral Sci.* 48, 85–88.