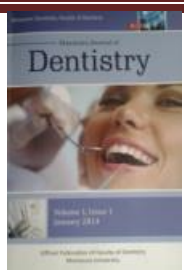
Cleaning Technique of Oval Shaped canals



Marwa Nageeb Abduljalil
Faculty of Dentistry, Mansoura University
Dr. Amany El-Said Badr
Professor of Endodontics, Endodontic Department
Faculty of Dentistry, Mansoura University
Dr. Mohamed Ossama
Assistant Professor of Endodontics, Endodontic Department
Faculty of Dentistry, Mansoura University

Abstract:
One of the major procedural steps in endodontic treatment is to thoroughly remove debris, pulp tissue, and microorganisms from the root canal system by means of chemo-mechanical preparation[1]. Chemo-mechanical preparation of the root canal through a combination of mechanical instrumentation and antibacterial irrigation is the critical stage in canal disinfection[2].

Introduction

The root canal treatment is a combination of biological and mechanical preparation of the root canal system [3]. From a biological aspect, the goals of chemo-mechanical preparation are to eliminate micro-organisms from the root canal system, to remove pulp tissue that may support microbial growth, and to avoid forcing debris beyond the apical foramen which may sustain inflammation[2]. while the mechanical aspect is mainly concerned with the shaping of canals into a more uniform and conically tapered space [4]. This space is prepared to contain the root filling material and allow more of the antimicrobial irrigating agents to flow deep into the canals.

However, currently no instrument can predictably clean the entire root canal system[5,6], and especially in the apical portion of the root canals, the cleaning efficiency is limited[7-10]. Thus, there is still controversy regarding the optimal size of apical root canal enlargement to maximize cleaning efficiency in this crucial part of the root canal (**Albrecht *et al.* 2004**, **Falk & Sedgley 2005**, **Bartha *et al.* 2006**).

For many years, the main factor involved in the success of root canal treatment was believed to be a hermetic sealing of the root canal system. Although the importance of a correct sealing cannot be denied, it is necessary to emphasize that successful treatment depends on elimination or drastic reduction of irritating agents inside the root canal and prevention of re-infection[11].

Pulp death and subsequent necrosis renders the root canal space undefended and provides an ideal warm and moist environment which has an abundant nutrient source to support microbial proliferation. This chamber acts as a barracks to harbor microorganisms in which they have the opportunity to develop pathogenicity and induce inflammatory disease of the per radicular tissue[12].

The intrinsic anatomy of the root canal system creates further challenges, emphasizing the necessity of proper disinfection measures. Isthmuses, inter-canal communications, curvatures and oval shaped canals can make disinfection a considerable challenge[22].

Cross-sectional root canal configurations have been classified as round, oval, long oval, flattened or irregular. **Metrically, Jou et al. (2004)**[23] defined "oval" as having a maximum diameter of up to two times greater than the minimum diameter and "long oval" as having a maximum diameter of two to four times greater than the minimum diameter.

Different instrumentation techniques have been described to prepare oval canals. These include the use of sonic and ultrasonic instruments, manual instrumentation or the use of rotary nickel-titanium (Ni-Ti) instrumentation techniques and finally reciprocating instrumentation techniques. None, however, has been shown to completely clean and shape the root canal and to maintain the oval shape outline form[24-29].

The oval shaped canals should have a different approach regarding management compared with normal root canal configurations.

Oval-shaped canals pose a significant challenge for adequate root canal cleaning, shaping, and disinfection, especially when rotary instruments are used for preparation[30]. This is because rotary instrumentation usually sculpts a round cross-sectional shape, which leaves behind untouched recesses in the extremities of the largest diameter of the oval canal.

Mandibular premolars typically present with a single root and a single canal. The solitary root is usually oval in cross section containing an oval cross-section canal. Canal configurations in mandibular premolars may vary significantly with respect to ethnicity, race, and sex[31].

Instruments with different designs and concepts have been introduced to deal with canals with complex anatomy, including oval-shaped canals. Anatomic irregularities are preferable sites for pulp tissues and debris to remain within the root canal system. Indeed, endodontic instruments must touch canal walls to clean and in those cases of anatomic complexities, cleaning is done solely by the flow and back flow of irrigating solutions.

The original NiTi files were based on a design with fixed tapered instruments and passive cutting radial lands file flutes. In order to improve ease of use, safety and efficiency, development from this point has concentrated on the following features of design: cutting flutes, variable tapers, the material, the motion and the cross section. Cutting flutes were introduced to improve efficiency and variable tapers to limit the cutting portion of the file to a specific point within the canal. More recently, advancement has taken place with NiTi metallurgy, motion and novel cross-sectional designs[12].

In NiTi files, the design is much more variable: the angle of cutting edges or the 'rake angle' can be negative, or in a very few designs positive[32]. Other variables include the number of cutting edges, and the size of the flutes which are the spaces between the cutting edges that allow clearing of the debris during cutting.

In addition to the shape of the cross section, NiTi files can also vary in the presence of additional features such as radial lands which are projections from the central axis of the file that are added to prevent screwing of the file into the root canal space while cutting [33]. The helical angle of the cutting edges is another feature, which can have a dissimilar pattern in some designs to again overcome a 'pulling-in' or 'screwing' effect [34].

Some authors believe that there is a relation between the instrument design and the root canal cleanliness[35,36,37]. There is some evidence that NiTi instruments with active cutting blades show better canal cleanliness than instruments with radial lands. **Liu *et al*[38]** compared the debris and smear layer production by ProTaper and GT instruments and found that the ProTaper produced more clean surfaces with less smear layer and debris. In another study by **Shahi *et al* 2009** [39], the ProFile instruments were compared with RaCe instruments and was found that RaCe instruments produced more clean surfaces.

Comparisons of instruments with and without radial lands on the basis of SEM evolution of root canal walls for residual debris have shown that radial lands tend to burnish the cut dentine into the root canal wall, whereas instruments with positive cutting angles seem to cut and remove the dentine chips[40,41]. **Jeon *et al*[36]** compared the thickness and debris penetration inside dentinal tubules after the use of HERO 642, ProFile and K3 instruments and found that the least smear layer remained in the HERO 642 group at the selected apical third of straight root canals and the surface texture of the smear layer, in addition to the depth and the frequency of packed materials into the dentinal tubules, varied with instrument type.

Veltri *et al*[42] reported that the blade angle of MTwo files is almost vertical and helical pitch increases from the tip to the handle. These features reduce the tendency for debris accumulation and to obtain an effective cutting action with less separation risks. Furthermore, the increasing pitch should allow a more delicate cutting action at the apex and a more aggressive one in the coronal portion.

Generations of the NiTi rotary instruments:

First Generation

This category of NiTi rotary instruments were first introduced to the market during the mid-1990s. The most important characteristic of the first-generation NiTi rotary file is having **passive** cutting radial lands along with fixed 0.04–0.06 tapers over the full working lengths. The main important NiTi rotary instruments within this category are LightSpeed Endodontics, Profile-Dentsply, Quantec-SybronEndo, and GT system-Dentsply. Several researches showed that all first-generation rotary instruments created smooth root canal walls which centered in the middle and caused low procedural errors.The main deficiency of this generation of NiTi rotary instruments was requiring numerous files to achieve these goals and complexity[43-46].

Second Generation

The second generation of NiTi rotary files was introduced into the market in 2001. These instruments had **active** cutting edges with greater cutting efficiency, so the number of instruments required to achieve complete cleaning and shaping was almost less in comparison with the previous generation. Notable systems in this generation are ProTaper Universal-Dentsply, K3-SybronEndo, Mtwo-VDW, Hero Shaper-Micro-Mega, I Race, and I Race Plus-FKG Dentaire.

Third Generation

It was in late 2007 that the manufacturers started to apply the heating and cooling technologies on NiTi alloys to improve the safety of these instruments, especially in the curved root canals.

In making third generation of the NiTi rotary files, the manufacturers have highly focused on metallurgic properties of the NiTi alloy using heating and cooling procedures on wires which results in reduction of the cyclic fatigue of the files and also reduction of the separation risk of the instruments which is highly demanded by the practitioners. Applying M-wire and R-phase technologies and electrical discharge methods make instruments with high memory shapes and low risk of separation[49,50].

K3 XF Files-SybronEndo, Profile GTX Series–Dentsply, controlled memory (CM) Files (HyFlex CM)–Coltene, and Vortex Blue (Dentsply Tulsa) are notable files in this group which have been exposed to heat treatments to increase flexibility and safety. The CM property helps the instrument to save the shape of the canal when it is moved out of the canal. Flex files (NeoEndo) files have been predisposed to gold thermal treatment which increases their cutting efficiency along with cyclic fatigue resistance[51,52].

Fourth Generation

Reciprocation which is described as any cyclic back and forth or up and down motion is another philosophy in canal

preparation which was first introduced by Blanc, a French dentist, in the late 1950s. Instead of full rotation, the reciprocating NiTi rotary instruments have movements in which clockwise and counterclockwise degrees of rotation are quite equal. The reciprocation theory of canal preparation has led to development of the fourth generation of NiTi rotary instruments. The use of a single file technique to achieve a thorough cleaning and shaping goals at this phase was another success which was also derived from the reciprocating philosophy in cleaning and shaping the root canal systems Many studies have shown that the Wave One and the One Shape single file systems can efficiently reduce the bacterial number in the root canal along with preserving the original shape of it. Wave One-Dentsply, self-adjusting le (SAF)-ReDent Nova, and Reciproc-VDW are featured instruments of fourth generation[43,51,53,54].

Fifth Generation

In this generation, the efficiency of canal shaping has been improved by offsetting the center of rotation. The offset designed files produce a mechanical wave of motion that distributes along the full length of the NiTi file which improves cutting and removing the debris in comparison with a centered mass rotating instrument. Furthermore, this offset design reduces the taper lock or the screwing effect which causes instrument separation. HyFlex electrical discharge machining (EDM) Coltene, Revo-S Micro-Mega, One Shape Micro-Mega, and ProTaper Next-Dentsply are important files of the fifth generation[51].

ProTaper Gold (PTG):

ProTaper Gold is the latest addition to the world famous ProTaper family developed by Dentsply Sirona Endodontics in collaboration with international endodontic key opinion leaders.

They have the same geometries as ProTaper Universal with a convex triangular cross section and progressive taper with regard to the morphology, including sizes, taper, and cross-section. It is distinguished by the Gold thermal treatment, which increases its flexibility and resistance to cyclic fatigue, helping ensure a more centered preparation of curved canals[62]. Post heat treatment is applied after the flutes of a file have been manufactured. The temperature used is in a range of 370-510°C for a variable period of time. Files exhibit two stage specific transformation behavior and high Af temperature around 50°C similar to CM wire[70].

ProTaper Gold (PTG) files (Dentsply Tulsa Dental Specialties) have featured manufactured metallurgical characteristics with 2-stage specific transformation behavior and high austenite finish temperatures[63]. ProTaper Gold files are available in eight sizes: SX (tip size 19 with a taper of 0.04), S1 (tip size 18 with a taper of 0.02), S2 (tip size 20 with a taper of 0.04), F1 (tip size 20 with a taper of 0.07), F2 (tip size 25 with a taper of 0.08), F3 (tip size 30 with a taper of 0.09), F4 (tip size 40 with a taper of 0.06), and F5 (tip size 50 with a taper of 0.05 [64]and use the same rotary action and settings as ProTaper Universal.

According to **Dr. John West**; "ProTaper Gold produces consistently predictable shapes for predictable cleaning and obturation that is easier and safer than ever before."

Single-File Rotary Systems

Single-file rotary systems are classified to two groups: continuous rotating and reciprocating files, based on type of their motions[58].

Wave One Dentsply-Maillefer, Swiss, and Reciproc VDW, Germany, have reciprocating motions while Neoniti–Neolix, Charles-La-Foret, France, One Shape Micro-Mega, HyFlex/EDM-Coltene, Whaledent-Swiss, and XP-endo shaper FKG Swiss apply continuous motions.

This perfect combination of flexibility and fracture resistance makes it possible to reduce the number of files required for cleaning and shaping during root canal treatment without having to dismiss preservation of the original curve and anatomy of the root canal[53,59,60].

XP endo shaper:

Recently, a special NiTi alloy known as MaxWire (Martensite-Austenite Electropolishing-Flex, FKG). The XP endo shaper (FKG Dentaire, La-Chaux-de-Fonds, Switzerland) was introduced in 2016 with 0.30 diameter and 0.1 taper that could expend to 0.4 taper. This file has a retracted form to rectilinear geometry when it is in a martensitic phase (rest position or static) and a structured form when in the austenite phase (working position or dynamic state). The transition from the martensite phase to the austenite phase occurs naturally in the body temperature between 32°C and 37°C with Af temperature around 35°C. In dynamic state, the instrument has a twisted shape, with several twists twisted along its length.

It has a Booster tip that gives it a unique geometry, with six cutting edges at the tip and it has the ability to start shaping at ISO 15 initial diameter and achieve ISO diameter 30, but also to increase the taper from .01 to at least .04. it allows to reach a final canal preparation of minimum 30/.04 and this with only one instrument.

Lacerda et al 2017 evaluated the cleaning and shaping ability of 3 instrumentation systems in oval canals of extracted vital teeth using a correlative analytic approach. There was no significant difference in the amount of unprepared surface areas between the 3 instrument systems, except for the comparison between the SAF and XP-endo Shaper in the apical 4-mm segment. None of them prepared 100% of the root canal walls. The cleaning ability of the 3 systems was similar.

One curve:

One Curve is a single-use, heat-treated NiTi rotary file that enables shaping of the full length of the canal with a single instrument, directly to the apex. Combined with the patented design, C. wire defines One Curve's personality traits as its own DNA: One Curve is a smart, efficient, and conservative instrument manufactured by Micro-Mega Company. The advantages of One Curve, single- file technology are listed below:

1. Increased blade flexibility and more separation resistance resulted from C. wire heat treatment technology: CM of NiTi material
2. Perfect taper and diameter for a final shaping that meets standards of an optimized cleaning and shaping.

3. Patented variable cross-section all along the blade for a centering ability in the apical third and an excellent debris removal up to the medium and coronal parts
4. Proven cutting efficiency
5. Preserves the original anatomy of the root canal[66,67].

Controlled memory (CM) wire of NiTi material: CM Wire (DS Dental, Johnson City, TN) is a novel NiTi alloy with flexible properties that was introduced in 2010. It is manufactured by a proprietary thermo-mechanical process aimed to increase the flexibility, reduce the shape memory, raise the transformation temperatures (Af to about 50°C) and obtain stable martensite at the body temperature. This allows the instruments to be pre-curved prior to placing them into the root canal. Sterilization of the files will return them to their original shape. CM NiTi file systems available also include Hyflex CM (Coltene Whaledent, USA), Typhoon CM (Clinician's Choice Dental Products, USA) and ProFile Vortex Blue (Dentsply).

Today, thermal treatment of NiTi alloys helps us to optimize the mechanical properties and increase the flexibility of these instruments [68]. The mechanical properties of NiTi depend on its crystallographic arrangement, which can exist in two forms depending on the temperature and stress. At higher temperatures, NiTi exists in an austenitic phase, where the atoms are arranged in a body centered cubic lattice[69]. When stress is applied or temperature is reduced below a certain range described as the transformation temperature the atoms tend to rearrange their distribution into a more elastic form called the martensitic phase. This transformation is what gives the NiTi its super elasticity.

References

1. ***Quality guidelines of endodontic treatment: consensus report of the European Society of Endodontology. Int Endod J 2006;921–30.***
2. ***Young, G. R., P. Parashos, and H. H. Messer. "The principles of techniques for cleaning root canals." Australian Dental Journal 52 (2007): S52-S63.***
3. ***Peters OA, Peters CI, Basrani B. 2015 Cleaning and shaping the root canal system. In Pathways of the pulp (eds MH Hargreaves, LH Berman, S Cohen), pp. 209 – 279. St Louis, MO: Elsevier.***
4. ***Schilder H. 1974 Cleaning and shaping the root canal. Dent. Clin. N. Am. 18, 269 – 296.***
5. ***Paqué F, Ganahl D, Peters OA. Effects of root canal preparation on apical geometry assessed by micro-computed tomography. J Endod 2009; 35(7): 1056-9.***
6. ***Fornari VJ, Silva-Sousa YT, Vanni JR, Pécora JD, Versiani MA, Sousa-Neto MD. Histological evaluation of the effectiveness of increased apical enlargement for cleaning the apical third of curved canals. Int Endod J 2010; 43(11): 988-94.***
7. ***Ahlquist M, Henningsson O, Hultenby K, Ohlin J. The effectiveness of manual and rotary techniques in the cleaning of root canals: a scanning electron microscopy study. Int Endod J 2001; 34(7): 533-7.***
8. ***Gambarini G, Laszkiewicz J. A scanning electron microscopic study of debris and smear layer remaining following use of GT rotary instruments. Int Endod J 2002; 35(5): 422-7.***
9. ***Foschi F, Nucci C, Montebugnoli Le,t al.SEM evaluation of canal wall dentine following use of Mtwo and ProTaper NiTi rotary instruments. Int Endod J 2004; 37(12): 832-9.***
10. ***Paqué F, Musch U, Hülsmann M. Comparison of root canal preparation using RaCe and ProTaper rotary Ni-Ti instruments. Int Endod J 2005; 38(1): 8-16.***
11. ***Siqueira, José F., et al. "Histological evaluation of the effectiveness of five instrumentation techniques for cleaning the apical third of root canals." Journal of endodontics 23.8 (1997): 499-502.***
12. ***Tomson, Phillip L., and Stéphane R. Simon. "Contemporary cleaning and shaping of the root canal system." Primary dental journal 5.2 (2016): 46-53.***
13. ***Hess W. Formation of Root-Canals in Human Teeth "Zur Anatomie der Wurzelkanale des menschliches Gebisses," Schweizerische Vierteljahrsschrift fur Zahnheilkunde, 1917. Translated by Newton G. Thomas, AB, MA, DDS, and Herman Redlich, Chicago, Illinois. The Journal of the National Dental Association 1921; 8:704-34.***
14. ***Gu Y, Lu Q, Wang H, Ding Y, Wang P, Ni L. Root canal morphology of permanent three rooted mandibular rst molars-part I:pulp oor and root canal system. J Endod. 2010; 36:1341-46.***
15. ***Filpo–Perez C, Bramante CM, Villas-Boas MH, Duarte MAH, Versiani MA, Ordinola-Zapata R. Micro-computed tomographic analysis of the root canal morphology of the distal root of mandibular rst molars. J Endod. 2015; 41:231-36.***
16. ***Tahmasbi M, Jalali P, Nair K, Madhu KN, Sevin B, Nair UP. Prevalence of middle mesial canals and isthmi in the mesial root of mandibular molars:an in vivo cone- beam computed tomographic study. J Endod. 2017; 43:1080-83.***
17. ***Ballullaya SV, Vemuri S, Kumar PR. Variable permanent mandibular rst molar: review of literature. J Conserv Dent. 2013; 16:99-110.***

18. *R. D'Souza, "Development of the pulpodentinal complex," in Seltzer and Bender's Dental Pulp, K. Hargreaves, Ed., Quintessence Books, Chicago, Ill, USA, 2002.*
19. *ElAyouti A, Chu AL, Kimionis I, Klein C, Weiger R, Lost C. Efficacy of rotary instruments with greater taper in preparing oval root canals. Int Endod J 2008; 41: 1088-92.*
20. *Barbizam JV, Fariniuk LF, Marchesan MA, Pecora JD, Sousa-Neto MD. Effectiveness of manual and rotary instrumentation techniques for cleaning flattened root canals. J Endod 2002; 28: 365-6.*
21. *Zmener O, Pameijer CH, Banegas G. Effectiveness in cleaning oval-shaped canals using Anatomic Endodontic Technology, ProFile, and manual instrumentation: a scanning electron microscopic study. Int Endod J 2005; 38: 356-63.*
22. *Siqueira JF Jr, Alves FR, Almeida BM, de Oliveira JC, Rôças IN. Ability of chemomechanical preparation with either rotary instruments or self-adjusting file to disinfect oval-shaped root canals. J Endod 2010; 36: 1860-5.*
23. *Jou Y-T, Karabuchak B, Levin J, et al. Endodontic working width: current concepts and techniques. Dent Clin North Am 2004; 48: 323-35.*
24. *Lumley PJ, Walmsley AD, Walton RE, Rippin JW. Cleaning of oval canals using ultrasonic or sonic instrumentation. J Endod 1993; 19:453-7.*
25. *Wu MK, van der Sluis LW, Wesselink PR. The capability of two hand instrumentation techniques to remove the inner layer of dentine in oval canals. Int Endod J 2003; 36: 218-24.*
26. *ElAyouti A, Chu AL, Kimionis I, Klein C, Weiger R, Lost C. Efficacy of rotary instruments with greater taper in preparing oval root canals. Int Endod J 2008; 41: 1088-92.*
27. *Barbizam JV, Fariniuk LF, Marchesan MA, Pecora JD, Sousa-Neto MD. Effectiveness of manual and rotary instrumentation techniques for cleaning flattened root canals. J Endod 2002; 28: 365-6.*
28. *Zmener O, Pameijer CH, Banegas G. Effectiveness in cleaning oval-shaped canals using Anatomic Endodontic Technology, ProFile, and manual instrumentation: a scanning electron microscopic study. Int Endod J 2005; 38: 356-63.*
29. *Grande NM, Plotino G, Butti A, Messina F, Pameijer CH, Somma F. Cross-sectional analysis of root canals prepared with Ni-Ti rotary instruments and stainless steel reciprocating files. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007; 103: 120-6*
30. *Jou YT, Karabucak B, Levin J, Liu D. Endodontic working width: current concepts and techniques. Dent Clin North Am 2004; 48:323–35.*
31. *F. J. Vertucci, "Root canal morphology and its relationship to endodontic procedures," Endodontic Topics, vol. 10, pp. 3–29, 2005.*
32. *Guelzow A, Stamm O, Martus P, Kielbassa AM. 2005 Comparative study of six rotary nickel – titanium systems and hand instrumentation for root canal preparation. Int. Endod. J. 38, 743 – 752. (doi:10. 1111/j.1365-2591.2005. 01010.x).*
33. *Hu¨lsmann M, Bluhm V. 2004 Efficacy, cleaning ability and safety of different rotary NiTi instruments in root canal retreatment. Int. Endod. J. 37, 468 – 476. (doi:10. 1111/j.1365-2591.2004. 00823.x)*
34. *Bergmans L, Van Cleynenbreugel J, Wevers M, Lambrechts P. 2001 Mechanical root canal preparation with NiTi rotary instruments: rationale, performance and safety. Am. J. Dent. 14, 324 – 333.*
35. *Yang, Guobin, et al. "Scanning electron microscopic evaluation of debris and smear layer remaining following use of ProTaper and Hero Shaper instruments in combination with NaOCl and EDTA irrigation." Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology 106.4 (2008): e63-e71.*
36. *Jeon, In-Soo, et al. "Smear layer production by 3 rotary reamers with different cutting blade designs in straight root canals: a scanning electron microscopic study." Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology96.5 (2003): 601-607.*
37. *Kum, Kee-Yeon, et al. "Smear layer production of K3 and ProFile Ni-Ti rotary instruments in curved root canals: a comparative SEM study." Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology 101.4 (2006): 536-541.*
38. *Liu, S. B., et al. "Cleaning effectiveness and shaping ability of rotary ProTaper compared with rotary GT and manual K-Flexofile." American journal of dentistry 19.6 (2006): 353-358*
39. *Shahi, Shahriar, et al. "A comparative scanning electron microscopic study of the effect of three different rotary instruments on smear layer formation." Journal of oral science51.1 (2009): 55-60.*
40. *Versümer, J., M. Hülsmann, and F. Schäfers. "A comparative study of root canal preparation using ProFile. 04 and Lightspeed rotary Ni–Ti instruments." International Endodontic Journal 35.1 (2002): 37-46.*

41. *Hülsmann, M., G. Gressmann, and F. Schäfers. "A comparative study of root canal preparation using FlexMaster and HERO 642 rotary Ni–Ti instruments." International endodontic journal 36.5 (2003): 358-366.*

42. *Veltri, M., et al. "A comparative study of Endoflare–Hero Shaper and Mtwo NiTi instruments in the preparation of curved root canals." International Endodontic Journal 38.9 (2005): 610-616.*

43. *Haapasalo M, Shen Y. Evolution of nickel-titanium instruments: From past to future. Endod Topics 2013; 29:3-17.*

44. *Deepak J, Ashish M, Patil N,Kadam N, Yadav V, Jagdale H, et al. Shaping ability of 5th generation Ni-Ti rotary systems for root canal preparation in curved root canals using CBCT: An in vitro study. J Int Oral Health 2015; 7:57-61.*

45. *Bryant ST, Dummer PM, Pitoni C, Bourba M, Moghal S. Shaping ability of 04 and 06 taper ProFile rotary nickel-titanium instruments in simulated root canals. Int Endod J 1999; 32:155-64.*

46. *Yun HH, Kim SK. A comparison of the shaping abilities of 4 nickel-titanium rotary instruments in simulated root canals. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2003; 95:228-33.*

47. *De-Deus, Gustavo, and Paulo Garcia-Filho. "Influence of the NiTi rotary system on the debridement quality of the root canal space." Oral Surgery, Oral Medicine, Oral Pathology, Oral Radiology, and Endodontology 108.4 (2009): e71-e76.*

48. *da Frota, Matheus Franco, et al. "Cleaning capacity promoted by motor-driven or manual instrumentation using ProTaper Universal system: Histological analysis." Journal of conservative dentistry: JCD 16.1 (2013): 79.*

49. *Kuzekanani M, Naja pour R. Prevalence and distribution of radix paramolaris in mandibular rst and second molars of an Iranian population. J Int Soc Prev Community Dent 2018; 8:240-44.*

50. *Ha JH, Kim SK, Cohenca N, Kim HC. Effect of R-phase heat treatment on torsional resistance and cyclic fatigue fracture. J Endod 2013; 39:389-93.*

51. *Peters OA, Gluskin AK, Weiss RA, Han JT. An in vitro assessment of the physical properties of novel Hy ex nickel-titanium rotary instruments. Int Endod J 2012; 45:1027-34.*

52. *Ruddle CJ, Machtou P, West JD. The shaping movement: Fifth-generation technology. Dent Today 2013; 32:94, 96-9.*

53. *The New Niti File Generation, Hyflex TM, A Miracle of Flexibility and Fracture Resistance. Available from: http://www.colten.com. [Last accessed on 2018 May 12].*

54. *Nabeshima CK, Caballero-Flores H, Cai S, Aranguren J, Borges Britto ML, Machado ME, et al. Bacterial removal promoted by 2 single-le systems: Wave one and one shape. J Endod 2014; 40:1995-8.*

55. *De-Deus, Gustavo, et al. "The self-adjusting file optimizes debridement quality in oval-shaped root canals." Journal of endodontics 37.5 (2011): 701-705.*

56. *de Melo Ribeiro, Marcus Vinícius, et al. "Comparison of the cleaning efficacy of self-adjusting file and rotary systems in the apical third of oval-shaped canals." Journal of Endodontics39.3 (2013): 398-401.*

57. *Shetty, Vikram, et al. "HISTOLOGICAL EVALUATION OF THE EFFECTIVENESS OF THREE ROTARY SYSTEMS FOR CLEANING THE APICAL THIRD OF ROOT CANALS."*

58. *Moazzami F, Khojastepour L, Nabavizadeh M, Seied Habashi M. Cone-beam computed tomography assessment of root canal transportation by Neoniti and Reciproc single-le systems. Iran Endod J 2016; 11:96-100.*

59. *Singh H, Kapoor P. Hy ex CM and EDM les: Revolutionizing the art and science of endodontics. J Dent Health Oral Disord Ther 2016; 5:00182.*

60. *Kaval ME, Capar ID, Ertas H. Evaluation of the cyclic fatigue and torsional resistance of novel nickel-titanium rotary les with various alloy properties. J Endod 2016; 42:1840-3.*

61. *De-Deus, Gustavo, et al. "Suboptimal debridement quality produced by the single-file F2 ProTaper technique in oval-shaped canals." Journal of Endodontics 36.11 (2010): 1897-1900.*

62. *Gagliardi J, Versiani MA, de Sousa-Neto MD, Plazas-Garzon A, Basrani B. Evaluation of the shaping characteristics of ProTaper Gold, ProTaper NEXT, and ProTaper universal in curved canals. J Endod. 2015 Oct;41(10):1718-24.*

63. *UygunAD,KolE,TopcuMK,etal.Variationsincyclicfatigueresistanceamong Pro- Taper Gold, ProTaper Next and ProTaper Universal instruments at different levels. Int Endod J 2016; 49:494–9.*

64. ***Dentsply Tulsa. The ProTaper Gold Brochure; 2014.***

65. ***Al-Khafaji, Hussein A., and Hussain F. Al-Huwaizi. "Cleaning Efficiency of Root Canals using Different Rotary Instrumentation Systems: A Comparative In vitro Study." International Journal of Medical Research & Health Sciences8.1 (2019): 89-93.***

66. ***OneCurve-MICRO-MEGA.***

67. ***D'Amario M, De Angelis F, Mancino M. Canal shaping of different single- file systems in curved root canals. J Dent Sci 2017; 12:328-32.***

68. ***ElAyouti A, Chu AL, Kimionis I, Klein C, Weiger R, Lost C. Efficacy of rotary instruments with greater taper in preparing oval root canals. Int Endod J 2008; 41: 1088-92.***

69. ***Thompson SA. 2000 An overview of nickel–titanium alloys used in dentistry. Int. Endod. J. 33, 297 – 310. (doi:10.1046/j.1365-2591.2000. 00339.x).***

70. ***Hieawy A, Haapasalo M, Zhou H, Wang ZJ, Shen Y (2015) Phase Transformation Behavior and Resistance to Bending and Cyclic Fatigue of ProTaper Gold and ProTaper Universal Instruments. J Endod 41(7): 1134-1138.***