UNIVERSIDADE DE SÃO PAULO
FACULDADE DE ODONTOLOGIA DE BAURU

ERICSON JANOLIO DE CAMARGO

The influence of new heat–treated NiTi alloy on shaping ability and apical transportation of maxillary molars. The evaluation of the larger apical preparation on mesiobuccal and distobuccal canals of maxillary molars: A micro-computed study

Influência de diferentes tratamentos na liga de Ni-Ti no preparo e transporte apical de molares superiores. Avaliação do efeito da variação do diâmetro do preparo apical de canais mesio-vestibulares e disto-vestibulares de molares superiores: análise por meio de microCT.

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Tese constituída por artigos apresentada a Faculdade de Odontologia de Bauru da Universidade de São Paulo para obtenção do título de Doutor em Ciências no Programa de Ciências Odontológicas Aplicadas, na área de concentração Endodontia.

Orientador: Prof. Dr. Rodrigo Ricci Vivan

Versão Corrigida

BAURU

2017

Camargo, Ericson Janolio de

C14-i The influence of new heat–treated NiTi alloy on shaping ability and apical transportation of maxillary molars. The evaluation of the larger apical preparation on mesiobuccal and distobuccal canals of maxillary molars: A micro-computed study. /Ericson Janolio de Camargo. – Bauru, 2017.

144 p. : il. ; 30cm.

Tese (Doutorado) – Faculdade de Odontologia de Bauru. Universidade de São Paulo

Orientador: Prof. Dr. Rodrigo Ricci Vivan

Nota: A versão original desta tese encontra-se disponível no serviço de Biblioteca e Documentação da Faculdade de Odontologia de Bauru – FOB/USP.

Comitê de Ética em Seres Humanos
da FOB-USP
CAAE: 46767515.2.0000.5417
Data: 29/07/2015

FOLHA DE APROVAÇÃO

Ericson Janolio de Camargo

DADOS CURRICULARES

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DEDICATÓRIA

Dedico este trabalho aos meus pais, **Noel Nazário de Camargo (in memorian)** e **Alaíde Janolio de Camargo**. Obrigado por me ensinar, com o exemplo de vocês, que na vida devemos lutar, sermos honestos, fortes e justos com nossos semelhantes. Se hoje estou finalizando esta importante etapa, é graças ao amor e incentivo que recebi de vocês. Obrigado pelo amor incondicional e por todo apoio para a enfrentar as adiversidades da vida e vencer os desafios com caráter e dignidade. A vocês, todo o meu amor!

As minhas irmãs, **Erika** e **Evely**, pelo amor, companheirismo e por estarem sempre presentes, mesmo que fisicamente distantes. Isso foi essencial para me fortalecer nos momentos difíceis. A vocês, todo o meu amor e agradeçoa Deus nossa ligação eterna !

Aos meus cunhados, **Tadeu Vieira** e **Carlos Batista, que terminaram se tornando meus segundos irmãos**. A vocês, minha gratidão e amizade!

À toda a minha família, em especial ao meu tio **Jorge** (in memorian), por seu amor incondicional e por ter sido meu segundo pai. Um grande exemplo de homem de grande caráter. Minha eterna gratidão!

À minha tia **katia Embrize Janolio**, por todos os bons conselhos no período que convivemos e que sempre persistem na minha memória . Meu muito obrigado!

À minha tia **Shirley Janolio**, por todo amor e palavras de carinho. Obrigado por dividir a sabedoria de alguém que continua aprendendo muito com a vida. Por me ensinar a simplificar mais as coisas. Minha gratidão por todo amor e pela sua amizade!

A minha prima, **Aracy Janolio** (in memorian), que participou ativamente na minha educação e sempre me incentivou a estudar. Obrigado pelo seu amor e pelo exemplo de pessoa que foi na minha vida. Obrigado por não medir esforços, para ajudar contruir o meu sonho (ser dentista). Meu amor por você é eterno!

Agradeço a minha segunda mãe de Bauru, **Nereide Aparecida Soares**, por ter me recebido de braços abertos e ter me adotado com tanto amor. A você, minha grande gratidão!

A todos os meus amigos que fazem com que os dias sejam mais felizes. Obrigado por fazerem parte da minha vida, da minha história e estarão sempre na minha memória!

AGRADECIMENTOS

Agradeço à **Deus** por tantas graças e bênçãos na minha vida. Agradeço por ter me presenteado com o dom da vida, pela sabedoria que aos poucos, vai somando a passagem de cada fase e por me ter dado a oportunidade de realizar mais um sonho, ser doutorando da FOB-USP. Pai do Céu, obrigado! Sem Tí, nada seria possível.

Ao meu orientador e amigo, Prof. Dr. **Rodrigo Ricci Vivan**, o qual admiro pela sua capacidade e dedicação incansável à Endodontia. Seu ânimo e entusiasmo científico nos incentiva sempre a buscar mais. Obrigado pela confiança em mim . Obrigado pelo tempo dedicado aos ensinamentos, sempre disposto a colaborar e orientar. Seu esforço e capacidade fazem jus a carreira admirável que está construindo. Meu amigo, minha grande admiração por você e pela contribuição que tem dado ao departamento de endodontia da FOB-USP.

Ao meu primeiro orientador desta tese, Prof. Dr. **Ivaldo Gomes de Moraes**, o qual admiro pela sua dedicação à Endodontia e pelo seu exemplo ímpar de ser humano. Obrigado pela confiança e por ter sempre me ensinado muito sobre muitas coisas, inclusive sobre endodontia. Você foi e é um exemplo para todos nós. Aprendemos com o senhor que é possível conciliarmos a competência com a fraternidade e a humildade. Suas palavras sempre sábias, com o olhar da experiência de um pai , que sabe que ensinar exige amor e paciência. Obrigado pela oportunidade de ter sido seu orientado no mestrado e iniciado a orientação no doutorado. Obrigado por tudo meu amigo!

Ao Prof. Dr. **Marco Antônio Húngaro Duarte**, pela convivência, paciência e pelo apoio durante o período do doutorado. O seu exemplo de dedicação incansável à docência e à Endodontia contagia e inspira os alunos a cada vez mais a se superar. Obrigado por realizar as análises estatísticas dos nossos trabalhos e pelas sugestões que sempre trouxeram engrandecimento. Obrigado por não medir esforços em nos ajudar. Ao senhor, toda a minha admiração e respeito!

Ao Prof. Dr. **Clovis Monteiro Bramante**, pelo seu exemplo de dedicação incansável à docência e à Endodontia. Agradeço a oportunidade de ter aprendido e trabalhado com o senhor. Obrigado pelo apoio e pelos direcionamentos, essenciais para que eu crescesse profissionalmente.

Ao professor Dr. **Roberto Brandão Garcia**, por ter feito parte da minha caminhada na pós-graduação. Por me ensinar a olhar sempre um detalhe a mais, em busca da excelência daquilo que se é proposto. Ao senhor, minha gratidão e respeito!

Ao professor Dr. **Norbertti Bernardineli**, por ter feito parte da minha caminhada na pós-graduação. Obrigado pelos ensinamentos. Ao senhor, minha gratidão e amizade!

À Profa. Dra. **Flaviana Bombarda de Andrade**. Obrigado por convivência sempre amigável e sempre disposta a nos ajudar. A senhora, minha gratidão e amizade!

Aos funcionários do departamento de Endodontia da FOB-USP, **Edimauro de Andrade**, **Suely Regina Bettio** e a ex-funcionária **Andressa Barraviera**. Obrigado pela convivência e amizade, e por estarem prontos a ajudar sempre que necessário.

Agradeço mais uma vez ao **Edimauro de Andrade**, pela presteza em colaborar em muitas fases deste trabalho, tornando-o possível de ser executado de forma mais ágil. A você meu amigo, minha imensa gratidão!

Agradeço aos colegas **Bruno Martini Guimarães, Jussaro Duque, Murilo Priori Alcalde, Lyz Cristina, Furquim, Pablo Amoroso, Vanessa Abreu Sanches Marques** por terem colaborado durante as diferentes fases do nosso trabalho. Sem a ajuda de vocês, eu não teria conseguido realizar este trabalho.

Obrigado pela amizade dos meus colegas das turma de mestrado e doutorado, **Arthur Lemos, Amanda Maliza, Bruno Martini Guimarães (Tomate), Bruno Piazza, Clarissa Rodrigues Teles, Denise Ferracioli Oda, Ericke Mucke Silva, Francine Cesário, Fernanda Fernandes, Gislene Cristina Vertuan, Glaucia, Jussaro Duque, Lyz Cristina Canali Furquim, Marcela Milanezi, Marcelo Pomini, Mariana Borges, Melissa Riviera, Michel Klymus, Milena Perraro Martins, Murilo Priori Alcalde, Pedro Titano, Rafaela Fernandes Zancan, Raquel Midena Mesquita, Renan Furlan, Talita Tartari, Vanessa Abreu Sanches Marques, Victor Cruz e Yahir Munhoz**. Obrigado pela convivência e por todos os bons momentos juntos ao longo destes anos.

Obrigado aos amigos **Pablo Amoroso, Bruno Cavenado e Murilo Priori Alcalde pela grande ajuda com os experimentos na fase da microtomografia computadorizada** (μCT). Aprendi muito com vocês. Agradeço e admiro a dedicação de vocês. Obrigado por terem compartilhado o conhecimento comigo nessa fase experimental.

A minha amiga e colega, **Clarissa Teles Rodrigues**, pelo companheirismo e por tantos bons momentos. A minha grande admiração pelo seu compromisso e capacidade. Obrigado pelo seu grande ombro amigo em todos os momentos e por ter me incentivado sempre nesta caminhada.

Obrigado ao meu grande amigo, **Antônio Carlos Gargioni Filho**, por ter me incentivado a ingressar na pós-graduação, pelo seu exemplo de comprometimento, honestidade, amizade e pelo seu companheirismo durante a fase dos meus estudos.

Agradeço à minha grande amiga e irmã, **Maria Divina de Jesus**, pela amizade incondicional e por participar da minha vida desde à infância. Obrigado por estar sempre presente em minha vida.

Agradeço à minha grande amiga e parceira de trabalho na Endodontia, **Andiara Roberto Ribeiro**. O seu apoio incondicional durante a fase do meu doutorado foi imprescindível, para que tudo desse certo durante as minhas ausências no Univag. Obrigado pelo comprometimento e por suprir as minhas ausências. Obrigado por me entender pelo olhar e por ser um grande exemplo de amizade!

Agradeço à **Nathália Galvão**, pela sua amizade tão sincera, intensa e presente. Uma amizade que nasceu de forma tão inesperada e que ganhou um espaço bem grande no meu peito. Muito obrigado!

Agradeço em oração ao meu amigo (in memorian), **Aroldo Almeida dos Santos**, pelo exemplo de amizade e dedicação. Um amigo que me inspirou muito a buscar pela execelência e comprometimento com a educação. Obrigado pela brevidade de nossa convivência, em uma fase tão importante da minha vida.

Obrigado ao meu amigo, **Gustavo Bertholdo**, por compartilhar seus conhecimentos sobre noções em fotografia e didática, o que me refletiu muito no aprimoramento do meu trabalho. Meu muito obrigado!

Obrigado ao meu amigo, **Arlindo Tadeu Teixeira Aburad**, por ter auxiliado na minha pesquisa, cedendo as amostras necessárias para a realização deste estudo.

Agradeço ao **Rafael Soares** da empresa Kerr por ter gentilmente fornecido as limas twisted file adaptive avaliadas neste estudo.

Obrigado ao Centro Universitário de Várzea Grande-MT, pelo apoio e incentivo para que eu realizasse o curso de Doutorado. Agradeço a todos os professores por terem me dado suporte, em especial os professores: Andiara Roberto Ribeiro, Omar Zina, e Rafael Pillar, por terem contribuído tantas vezes durante as minhas ausências. Agradeço também todos os meus colegas das disciplinas de clínica integrada 1, clínica integrada 2, estágio supervisionado 1 e estágio supervisionado 2, por terem me dado o apoio necessário, durante a fase do doutorado, contribuindo com as atividades clínicas. Agradeço aos meus alunos, por terem compreendido os meus breves distanciamentos e por sempre terem me apoiado nesta caminhada.

Agradeço à Câmara Municipal de Cuiabá, pelo apoio para que eu realizasse o curso do doutorado. Agradeço todas as pessoas daquela casa de leis que de alguma forma colaboraram. Agradeço ao atual presidente daquela casa de Leis, Justino Malheiros Neto e aos presidentes anteriores, Aroldo Kuzai e Júlio Cézar Pinheiro (in memorian), por administrativamente terem apoiado meu crescimento profissional. Agradeço aos meus amigos do ambulatório daquela casa de leis, Aline de Paula Moreira Fedatto, Carla de Camargo Vianna, Dolírio Afonso Vilela Sobrinho, Jane Rosângela Leventi, João Leopoldo Baçan, Karina Peno de Barros, Nayara Badre de Teixeira Carvalho e Rodrigo Monteiro da Silva, por terem me ajudado durante as minhas ausências. Vocês fazem a diferença e tornam a minha manhã de trabalho muito prazeirosa.

Agradeço à Secretaria Municipal de Saúde de Cuiabá, por me apoiar durante a fase dos meus estudos. Agradeço também aos meus colegas de trabalho do centro de especialidades odontológicas: Alba M. Craveiro, Ana Paula Siqueira Ribeiro Tibalde, Andreia Garcia Moura Yassuda, Carla Roberta Nettson Galante, Carlos Eduardo da Silva Farina, Camila Aragón Dezordi Soares, Claudinete Lima Bueno de Moraes, Cristiane Javarroti Câmara Campos, Gislaine F erreira Martins, Deise Lúcia Akerley,

Erica Josiane Faustine Calixto de Almeida, Fernanda Silva De Assis, Gonçalo Francisco de Magalhães, Jeanne Correia Borges, Janaina Okada, João José do Nascimento, Laura Consuelo Amorim, Manuel Sebastião de Oliveira, Mara Antônia Alves de Arruda, Marcos Yassuda, Paulo Artur Andrade Albuquerque, Sérgio Souza Antunes, Simone Bezerra Oliveira.

AGRADECIMENTOS INSTITUCIONAIS

À Faculdade de Odontologia de Bauru, Universidade de São Paulo, na pessoa Diretora Profa. Dra. **Maria Aparecida de Andrade Moreira Machado**.

À Comissão de Pós-graduação na pessoa do Prof. **Dr. Guilherme dos Reis Pereira Janson**.

Ao Coordenador do programa de Pós-graduação em Endodontia Prof. Dr. **Marco Antonio Hungaro Duarte**.

Às funcionárias da Pós-Graduação **Ana Letícia Palombo Momesso**, **Fátima Cassador Carvalho** e **Leila Regina da Silva Yerga Sanches** por sempre estarem dispostas a atender e ajudar.

À funcionária do Comitê de Ética em Pesquisa em Seres Humanos da Faculdade de Odontologia de Bauru-USP **Maristela Petenuci Ferrari** pela contribuição para o desenvolvimento deste trabalho.

Á todos os professores e funcionários da Faculdade de Odontologia de Bauru da Universidade de São Paulo, que participaram e contribuíram para a realização deste trabalho.

RESUMO

Influência de diferentes tratamentos na liga de Ni-Ti no preparo e transporte apical de molares superiores. Avaliação do efeito da variação do diâmetro do preparo apical de canais mesio-vestibulares e disto-vestibulares de molares superiores: análise por meio de microCT.

O objetivo deste estudo foi avaliar o transporte do canal, a centralização do canal, a espessura dentinária, a alteração volumétrica e o tempo de trabalho de diferentes sistemas mecanizados de níquel-titânio compostos por ligas convencional (Mtwo) e tratados termicamente (CM-Wire (Prodesign R e Hyflex CM), M-Wire (Reciproc) e fase-R (Twisted file adaptive) em preparos de canais em molares superiores. O papel dos novos instrumentos de níquel titânio tratados termicamente em preparos apicais mais amplos de canais mésio-vestibulares e disto-vestibulares dos molares superiores foi avaliado, como também o preparo do canal mésio-palatino (CMP), por meio da microtomografia computadorizada (μ-CT). No estudo do canal mésio-palatino, 30 primeiros molares superiores com configuração tipo IV de Vertucci foram selecionados e divididos em 3 grupos (n = 10): Reciproc [REC; VDW, Munich, Germany], Prodesign R [PDR; Easy, Belo Horizonte, Brazil] and Mtwo [MO; VDW, Munich, Germany]. No estudo dos canais mésio-vestibulares e disto-vestibulares, o total de 45 molares superiores foram selecionados com angulação da raiz mésio vestibular de 20 a 30 graus e apresentando a raiz disto-vestibular com angulação de 0 a 5 graus, de acordo com a classificação de Weine. Os dentes foram aleatoriamente distribuídos em 3 grupos (n=15): Reciproc (40.06) [REC, VDW, Munich, Germany]; Hyflex CM (40.06) [HF, Coltene, Cuyahoga Falls, OH, USA]; e Twisted file Adaptive (35.04) [TFA, SybronEndo, Orange, CA]. Após o preparo dos canais mésio-palatino, mésio-vestibular, e disto-vestibular, todos os dentes foram escaneados para avaliação dos parâmetros previamente citados. Especificamente, na avaliação do canal mésio-palatino, foi avaliada a porcentagem de canais que alcançaram patência. Todos os parâmetros foram avaliados estatisticamente pelo teste de Kruskal-Wallis e pelo teste Dunn's de múltipla comparação entre grupos, com nível de significância de 5%. O canal mésio-palatino não apresentou diferença estatisticamente significante em relação ao transporte, centralização, remanescente de dentina no terço cervical, quanto ao número de espécime abaixo de 0,5 mm de espessura na zona de perigo e no volume apical ($P>0.05$). O volume total do canal no grupo MO diferenciou-se do volume total do grupo PDR ($P<0.05$), enquanto essa diferença

não foi evidenciada entre os grupos REC comparado aos grupos MO e PDR ($P>0.05$). O grupo PDR demandou maior tempo para atingir o comprimento de trabalho comparado aos sistemas MO e REC. Na análise dos canais MV e DV dos molares superiores, o transporte coronal direcionou-se para o interior da curvatura do canal, enquanto no terço apical o transporte direcionou-se para o lado externo da curvatura. O transporte apical no primeiro milímetro de ambos os canais (MV e DV) foi equivalente entre os grupos ($P>0.05$). O canal MV apresentou nos níveis 3 e 4 mm transporte do grupo Reciproc significantemente menor do que no grupo Hyflex CM ($P<0.05$). Em relação ao transporte apical, no canal DV, nos milímetros 2 e 4 apicais do grupo Reciproc transportou significantemente mais comparado ao grupo TFA ($P<0.05$). Contudo, a centralização apical de ambos os canais e a quantidade de remanescente dentinário apical não se diferiram estatisticamente ($P<0.05$). O preparo do canal MV foi mais rápido com o sistema TFA comparado ao Reciproc e do Hyflex CM ($P<0.05$), enquanto no canal DV não foi evidenciado diferenças em relação ao tempo de preparo ($P>0.05$). A porcentagem e o volume de dentina removida em todo o canal e na região apical, após o preparo do canal apresentou diferenças significantes entre os grupos. O grupo TFA teve as menores porcentagens e valores de dentina removida no volume total do canal e no volume apical, em ambos os canais, comparado com os sistemas Reciproc e Hyflex CM ($P<0.05$). No canal MP, os três sistemas avaliados prepararam e patenciaram semelhantemente os canais MP. Contudo, o sistema Reciproc foi mais rápido para alcançar o comprimento de trabalho do que o sistema Prodesign R. Os grupos Mtwo e Reciproc removeram mais dentina na região voltada para o interior da furca quando comparado ao Prodesign R. Os sistemas compostos por ligas tratadas termicamente em preparos com maior ampliação apical mantiveram a morfologia dos canais MV e DV. Os sistemas promoveram discretos transportes, sem evidência de erros no preparo. Contudo, essas variações não são passíveis de significância clínica. O grupo do TFA foi mais rápido e promoveu menores alterações nos parâmetros volumétricos. O grupo do TFA foi capaz de preservar a anatomia original do canal com menor grau de transporte comparado ao Reciproc e Hyflex CM.

Palavras-chave: Tratamento de Canal Radicular; Sistemas Reciprocantes; Sistemas Rotatórios, Transporte Apical; Microtomografia computadorizada.

ABSTRACT

The influence of new heat–treated NiTi alloy on shaping ability and apical transportation of maxillary molars. The evaluation of the larger apical preparation on mesiobuccal and distobuccal canals of maxillary molars: A micro-computed study

The aim of this study was to evaluate canal transportation; centering ability; dentin thickness; change in volume, and time spent on shaping ability of maxillary molars prepared with mechanized NiTi file systems composed of a conventional NiTi alloy (Mtwo), a CM-Wire (Prodesign R and Hyflex CM) NiTi alloy, R-phase (Twisted File Adaptive) and an M-Wire (Reciproc) NiTi alloy]. With the purpose of understanding the role of new treated NiTi alloys in larger apical preparations, this type of preparation was evaluated in the mesiobuccal (MB) and distobuccal canal (DB) of maxillary molars, as well as, in the second mesiobuccal (MB2) canals in extracted maxillary first molars by means of micro-computed tomographic (micro-CT) imaging. For the second mesiobuccal canal (MB2) evaluation, thirty maxillary molars with Vertucci type IV canal configuration were selected and randomly divided into 3 groups (n = 10): Reciproc [REC; VDW, Munich, Germany], Prodesign R [PDR; Easy, Belo Horizonte, Brazil] and Mtwo [MO; VDW, Munich, Germany]. To assess the mesiobuccal and distobuccal canals, a total of 45 extracted maxillary molars were selected according to the following criteria: MB canals exhibiting curvatures according to the Weine classification in the 20-30 degree range; and DB canals presenting curvatures in the 0-5 degree range. These teeth were randomly assigned to three groups, Reciproc (REC) [40.06]; Hyflex CM (HF) [40.06] [Coltene, Cuyahoga Falls, OH, USA] and Twisted file Adaptive (TFA) [35.04]. After root canal preparation, all the teeth were scanned to evaluate parameters previously cited. In particular, the percentage of negotiability of the MB2 canal was evaluated. All parameters were statistically compared using the Kruskal-Wallis and Dunn's Multiple comparison tests within groups with a significance level of 5%. For MB2 canals, no statistically significant difference was observed among the three groups with regard to the values of canal transportation, centering ability, remaining dentin thickness in the coronal third, number of specimens with thickness under 0.5 mm in the danger zone, and apical volume ($P>0.05$). However, the entire volume of the canal in Group MO differed statistically from that of Group PDR ($P<0.05$), but Group REC did not differ statistically from Groups MO and PDR ($P>0.05$). Group PDR demanded more time to reach WL than use of the MO and REC

systems. For MB and DB canals, the trend of canal transportation was towards inner curvature in apical third, while in the coronal third it was towards the outer curve. There was no difference in apical transportation values in the first apical millimeters for both canals. In MB canal, at 3 and 4 mm, the Reciproc transportation value was significantly lower than that of Hyflex CM($P<0.05$). In the DB canal, at 2 and 4 mm, Reciproc showed substantially higher values than Group TFA ($P<0.05$). There was no statistically significant difference between the two canals among the three systems for centering ability in the apical third and the remaining dentin thickness (RDT). For DB canal, there was no significant difference in shaping time, but in the MB canal, Group TFA was swifter than Reciproc and Hyflex CM. The initial changes in volume (apical/entire) after canal preparation was statistically significant within groups in MB and DB canals for percentage and volume of dentin removed. TFA had the lowest values for the apical and entire volumes of dentin removed in both canals compared with Reciproc and Hyflex CM ($P<0.05$). TFA had the lowest percentage of dentin removed from the entire MB canal, and from the apical and entire volume of DB canal. For negotiating and shaping the MB2 canal, the three file systems had similar performance. However, the REC system reached the full working length faster than PDR. The MO and REC systems removed more dentin in the inner furcation area when compared with PDR. For MB and BD canals, the heat treated NiTi alloy systems used for larger apical preparation evenly maintained the morphology of the MB and DB canals of maxillary molars. In shaping procedures, the larger apical preparation produced slight canal transportation without evidence of significant preparation errors. However, these variations may not be feasible of clinical significance. Use of TFA was swifter for preparing the MB canal and produced fewer changes in volume parameters. The TFA system was able to preserve the original canal anatomy with less canal transportation than the Reciproc and Hyflex CM systems.

Keywords: Root canal treatment; Reciprocating systems; Rotary systems; apical transportation; micro-computed tomography.

LIST OF ABBREVIATIONS AND SYMBOLS

%	percentage
x	times
<	less than
>	more than
=	equal
≅	approximately similar
º	degree
CM	controlled memory
cm	centimeter
EDTA	ethylenediaminetetraacetic acid
KV	Kilovolts
MA	milliamp
microCT	computed microtomography
min	minutes
mL	milliliter
mm	millimeter
mm^2	square millimeter
mm^3	cubic millimeter
MO	Mtwo
M-Wire	Memory-Wire
n	number
NaOCL	sodium hypochlorite
NiTi	Nickel Titanium
P	statistical significance
PDR	Prodesign R
R-Phase	R-Phase
REC	Reciproc
rpm	revolutions per minute
µm	micrometer

SUMMARY

1 INTRODUCTION

1 INTRODUCTION

Cleaning, shaping and three-dimensional canal filling are the keys to a successful endodontic treatment, and these procedures demand knowledge of and respect for the anatomy of the root canal system (SHAKOUIE et al.,2013; ESKANDARINEZHAD;GHASEMI, 2012; RAHIMI; GHASEMI, 2013). Thorough knowledge of root canal anatomy is the first step in successful root canal treatment (VERTUCCI,1984). Some anatomical peculiarities may make it difficult to perform endodontic therapy, and are assumed to be the central factor leading to outcomes of failure (VERTUCCI,1984). Consequently, clinicians should be aware of the general configuration and possible anatomical differences to recognize them in root canal treatment. Typically, there are many complexities of the root canal system of first and second molar roots (KULID; PETERS, 1990; STROPKO, 1999; CLEGHORN; CHRISTIE; DONG, 2006). Some factors found in the anatomy of maxillary molars are a challenge in root canal instrumentation, even to skilled and experienced clinicians (VERTUCCI,2005). The second mesiobuccal canal (MB2) canals is evident in up to in 96% of the maxillary molars, and their pathway is so challenging that fewer than 80% could be fairly negotiated by the conventional technique using small hand files, even when using the operating microscope (GÖRDUYSUS; GÖRDUYSUS; FRIEDMAN,2001). In coronal third of maxillary molars, the distal surface of the mesial buccal root and mesial surface of the distal root have a thin wall, making those areas a danger zone during canal instrumentation (VERTUCCI,2005; DEGERNESS; BOWLES, 2010; ABOU-RASS; FRANK; GLICK, 1980). Apically, in preparation of the curved part of canals, transportation, straightening, or canal deviation may occur (SCHÄFER; DAMMASCHKE, 2006). Depending on the degree of transportation, this mishap may have impact on the clinical outcome of root canal treatment (SCHÄFER; DAMMASCHKE, 2006).

Since Walia, Brantley and Gerstein (1988) introduced the conventional NiTi files in Endodontics, these instruments have become indispensable for use in root canal therapy. Particularly for curved canals, the greater flexibility of this material is an advantage that made them more favorable instruments for use in shaping procedures. Recently, thermally treated Niti Alloys and manufacturing technologies involved in their production have improved the microstructure of conventional NiTi alloys and increased their flexibility (KUHN; TAVERNIER; JORDAN,2001; KUHN; JORDAN, 2002; HAYASHI et al., 2007; SHEN et al.,2013; ZHOU; PENG; ZHENG,2013). Furthermore, knowledge of the composition of NiTi alloy and the feature of microstructural phases is essential to determine the mechanical behavior of NiTi wires such as flexibility. From this aspect, heat treatment processing can adjust the transition temperature of NiTi alloy, which can determine the significant amount of one type of microstructural phase in clinical use (MCCORMICK; LIU, 1994; FRICK ET al.,2005; GUTMANN; GAO, 2012) and influence the torsional and fatigue resistance of NiTi endodontic files(SHEN et al.,2013a; ZHOU; PENG; ZHENG,2013; SHEN et al.2011b). For over two decades the conventional NiTi instruments have been considered appropriate to use for preparing curved canals correctly. These new advances in the manufacture of thermomechanically processed NiTi endodontic files have led to the introduction of NiTi files such as the M-Wire file (Reciproc; VDW, Munich, Germany); Controlled Memory Wire file (HyFlex; Coltene Whaledent, Cuyahoga Falls, OH), and R-Phase wire (Twisted File adaptive, SybronEndo, Orange, CA).

The Mtwo system (VDW, Munich, Germany) was launched in 2005, as the rotary multiple file system made of standard NiTi wire to prepare a canal using the single length technique. A feature of the cross-sectional design is an S-shaped and a noncutting safety tip. Thus, these instruments cut dentin efficiently, because of a positive rake angle with two cutting edges (SCHÄFER;ERLER; DAMMASCHKE,2006). Further, Mtwo instruments have a progressive pitch length (blade camber), which avoids the undesirable screw-in effect during shaping procedure, making this step safer (SCHÄFER;ERLER; DAMMASCHKE,2006). The system offers three options of instrument sequences for root canal preparation that include a basic sequence and two complementary sequences (Mtwo, User information). The basic series of Mtwo instruments is comprised of four instruments with tapers ranging between 4% and 6% and file sizes from 10 to 25 (10/.04;15/.05;20/.06;25/.06). There are two complementary sequences available, if the canal anatomy requires a larger apical preparation. The first, sequence one, consists of a series that includes six files with tapers ranging between 4% and 5% and file sizes from 30 to 60 (30/.05;35/.40;40/.04;45/.04;50/.04 and 60/.04). Sequence two contains 4 files with tapers ranging between 6% and 7% and sizes from 25 to 40 (30/.06; 35/.06;40/.06 and 25/.07). This system has been evaluated in numerous investigations of canal transportation, even in severely curved root canals (VALLAEYS; CHEVALIER; ARBAB-CHIRANI, 2016; YANG et. 2011; BÜRKLEIN; SCHÄFER, 2006), and its design has been characterized as favorable to shaping challenging canals (BÜRKLEIN; SCHÄFER, 2006).

In 2007, M-wire NiTi alloy (Memory Wire, Dentsply Tulsa Dental Specialties, Tulsa, OK, USA) was introduced into a process for manufacturing NiTi files that includes a sequence of heat treatments of NiTi wire blanks. This process resulted in a material containing martensite in its composition, leading to alloy strengthening (SHEN et al.,2013; ALAPATI et al., 2009b). In 2008, the first commercially available endodontic rotary system using the new M- Wire NiTi material was GTX. Later, in 2011, the Reciproc system (VDW, Munich, Germany) composed of M-Wire was presented as a single filing technique using reciprocating motion to prepare the canal. The system is used with a dedicated motor with reciprocating motion, whose movement occurs in wider angle of 150º in the counter-clockwise direction (cutting action) and a more acute angle of 30º in the clockwise direction (release of the file). This system is available in three sizes; 25/08(R25),40/06 (R40) and 50/05 (R50). The reciprocating action reduces pressure on the instrument, and therefore, decreases the development of cyclic fatigue caused by tension and compression in the shaping procedure (DE-DEUS et al., 2010a; VARELA-PATIÑO; 2010). The mode with the wider angle in the counterclockwise direction moves the file continuously toward the apex of the canal. Intentionally, the angles of the reciprocating drive are smaller than the elastic limit of the instrument. This movement originated from the balanced force technique proposed by Roane, enabling even curved canals to be safely prepared, with hand files for larger apical sizes (ROANE; SABALA; DUNCANSON, 1985).

In 2011, a new technology in NiTi alloy was launched By Coltene (Coltene Whaledent, Cuyahoga Falls, OH, USA) designated as Controlled Memory alloy. The novel thermomechanical process involves control of the material memory, generating remarkably flexible files, but without the shape memory of traditional NiTi instruments. Furthermore, the change in their composition consists of a lower percentage by weight of nickel (52% nickel by weight) than the typical 54.5% to 57% nickel by weight of most commercially available NiTi rotary files (ZINELIS ;ELIADES; ELIADES, 2010).The controlled memory process produces the more flexible files (SHEN et al.,2011a; SHEN et al.,2011b; TESTARELLI et al.,2011), with improved resistance to both cyclic fatigue and torsional fracture (SHEN et al.,2013a; ZHOU; PENG; ZHENG,2013; SHEN et al.2011b). Furthermore, this CM-Wire technology supported a decrease in the incidence of file fracture of up to 300% in a cyclical fatigue resistance test, when compared with conventional NiTi files (ZINELIS; ELIADES; ELIADES,2010; SHEN et al.,2011a; TESTARELLI et al.,2011; PETERS et al.,2012;). The CM-wire alloy offers reusable and autoclavable files for shaping canals. The main characteristic of the CM alloys is that they return to their original shape after autoclaving. If the file does not recover its initial shape, this means that the file is not usable and must be discarded to avoid file fracture. The HyFlex CM made from CM-wire is an innovative rotary multiple-file system available with different tips and tapers. The system has a coronal preflaring file tip 20 taper 0.08. The shaping file tips vary from 20 to 40 for tapers 0.04 and 0.06, and from 45 to 60 restricted to 0.04 taper. Another CM-wire file system is Prodesign R. This instrument launched in 2015, is a single-file reciprocating system (ProDesign R; Easy Equipamentos Odontológicos, Belo Horizonte, Brazil). The manufacturer claims that the ProDesign R file has an ISO size 25 at the tip and a taper of 0.06; and an ISO size 35 at the tip and a taper of 0.05. The features of the file are an S-shaped cross section, variable helical angles, and cutting in a clockwise direction. The particular composition of the microstructure of the crystal in CM-Wire alloy that demonstrates martensitic characteristics at room temperature (SHEN et al.,2012b), distinguishes it from the conventional NiTi metal alloy. Furthermore, the shift to the martensitic condition results in slight, or absence of shape memory that reduces the tendency towards straightening the canal during its application.

The twisted instruments made of R-phase wire were first introduced in 2008. The twisting process applied to this heat treated alloy provides it with superior flexibility and resistance to fatigue (GAMBARINI et al.,2008), because it prevents the crystalline structure from undergoing the grinding process. Later, the Twisted Files and Adaptive Motion Technology (Axis/SybronEndo, Orange, CA, USA) introduced in 2013, combined some features, such as the twisted design of an R-phase file operating in an adaptive motion. Particularly, the kinematics developed by the TFA motor adapts to the local challenges during instrumentation, combining continuous rotation, and reciprocating motion. If a slight or no imposed load is set, the instrument rotates and stops (360º-0º). If a file is under particular pressure from dentin or a load is applied, it changes to reciprocating motion (370CW/20-50CCW) (GERGI et al.,2015; KARATAŞ et al., 2016). These reciprocating angles change, depending on the anatomical complexities, and the intracanal force exerted on the instrument. The TF Adaptive system relies on only three files and is color coded according to a traffic light signal sequence: starts with green (SM1:20/.04 or ML1:25/.08), continues or stops with yellow(SM2:25/.06 or ML2:35/.06), and stops (SM3: 35/.05 or ML3:50/.04) with red (SHEN et al.,2011a). The R-phase heat treatment of files, twisting of the metal and specific surface conditioning (GERGI et al., 2015) provide them with more strength, flexibility and fatigue resistance (GAMBARINI et al., 2012), factors that ensure safety when shaping curved canals.

The following are the main advantages of the new heat treated NiTi files for canal cleaning and shaping: reduced canal transportation and ledging, diminished risk of file separation; a faster and more efficient shaping procedure (SHEN et al., 2013a; ZHOU;PENG; ZHENG, 2013). Recently, a clinical study (ZUOLO; CARVALHO;DE-DEUS GUSTAVO, 2015) presented a new approach to negotiating and preparing the MB2 canal easily with the use of a Reciproc R25, and up to 32% more effectively compared with hand files. Nevertheless, even with all improvements of the instruments, root canal system are often unsatisfactorily cleaned and shaped (GERGI et al.,2015). A strategy to reduce the non-instrumented area in the canal (FORNARI et al., 2010) and increase the apical third volume is to increase the apical preparation (BRUNSON et al., 2010; RODRIGUES et al.,2017). Moreover, larger apical preparation can reduce the bioburden (SIQUEIRA et al., 1999) with promising results in healing outcomes; and clinical and radiographic evaluations of patients with necrotic pulps and periapical lesions have been documented (AMINOSHARIAE; KULILD, 2015). On the other hand, the over-enlargement during the shaping procedure may weaken the dentin structure of the teeth (VERTUCCI et al.2005; SCHÄFER; DAMMASCHKE,2006; HÜLSMANN; PETERS; DUMMER, 2005). At present, X-ray micro–computed tomography has been used as a non-destructive and reproducible technology for investigating the shaping abilities of systems relative to their transportation/centering ability and assessing the volume of shaped canals (GERGI et al. 2015; GERGI et al. 2014; ZHAO et al.,2013; PEDULLÀ et al. 2016; SILVA et al., 2017). As far as we know, there is a lack of studies investigating the role of heat treated NiTi alloys for preparing the second mesiobuccal canals in maxillary first molars, and the effect of these files on larger apical preparations in mesiobuccal and distobuccal canals of maxillary molars, by means of micro–computed tomography (micro-CT) imaging.

Therefore, the aim of this study was to evaluate the influence of canal transportation; centering ability; dentin thickness; change in volume, and time spent on shaping using the different types of NiTi alloy instruments on preparation of the mesiobuccal canal, the second mesiobuccal canal and the distobuccal canal in maxillary molars. For this purpose, the study was performed in two steps:

1. Evaluation of instruments made of M-wire, CM-Wire and Conventional NiTi wire, used to negotiate and shape the second mesiobuccal canals of maxillary first molars, by using micro-computed tomography;

2. Evaluation of the three heat-treated NiTi instruments made of CM-wire, M-wire and R-phase, used to produce larger apical preparations in the mesiobuccal and distobuccal canals of maxillary molars, by using micro-computed tomography.

2 ARTICLES

2 ARTICLES

2.1 **ARTICLE 1**

Three Nickel-Titanium mechanized systems ability to negotiate and shape MB2 canals in maxillary first molars. A Micro-Computed Tomographic study

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Acknowledgments

The Corresponding Author[1] would like to thank the Cuiaba city council, Cuiaba Department of Health and the University Center of Várzea Grande for granting him time off during the studies.

The authors would like to express their sincere appreciation to their friend Prof Rodrigo Sanches Cunha for correcting the English grammar and for his accurate critical observation of this study.

The authors deny any conflicts of interest related to this study. This study was supported by the State of São Paulo Research Foundation, FAPESP (2014/25520-0).

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Abstract

Introduction: The aim of this study was to evaluate three mechanized NiTi file systems during the preparation of second mesiobuccal (MB2) canals in extracted maxillary first molars using a micro-computed tomography scanner (Micro-CT).
Methods: Thirty maxillary molars with Vertucci type IV canal configuration were selected and randomly divided into 3 groups (n = 10): Reciproc [REC; VDW, Munich, Germany], Prodesign R [PDR; Easy, Belo Horizonte, Brazil] and Mtwo [MO; VDW, Munich, Germany]. After root canal preparation, the teeth were scanned to evaluate two-dimensional (2D) parameters such as: canal transportation, centering ability in the apical and coronal thirds, the remaining dentin thickness in the coronal third, and the number of specimens with a thickness of under 0.5 mm in the danger zone. The three-dimensional (3D) parameters, such as increase in volume in the apical portion, and of the entire canal, were evaluated. Working time (WT) taken to achieve working length (WL) and shaping of the canal was also evaluated. The working time, 2 D and 3D parameters were statistically compared using the Kruskal-Wallis and Dunn Multiple comparison tests within groups, with a significance level of 5%.
Results: No statistically significant difference was found among the three groups with regard to canal transportation; centering ability; remaining dentin thickness in the coronal third; number of specimens with a thickness of under 0.5 mm in the danger zone, and the apical volume ($P>0.05$). However, the entire volume of the canal in Group MO was statistically different to PDR ($P<0.05$), but REC was not statistically different to Groups REC and PDR ($P>0.05$). Group PDR demanded more time to reach the WL than the MO and REC systems.
Conclusions: The three file systems had similar performance when negotiating and shaping the MB2 canal. However, the REC reached the full working length faster than PDR. The MO and REC systems removed more dentin in the inner furcation area when compared with PDR.

Keywords: Root canal treatment; Reciprocating systems; Rotary systems; apical transportation; Controlled memory wire; micro-computed tomography.

Highlights

* The tapered files (.06 and .08) produced at least 37.5% of samples with thinner remaining dentin thickness in the danger zone when the more flexible (CM-Wire).
* The less flexible files in this study such as M-Wire and Conventional NiTi instruments negotiated the MB2 canals in up to 60% of the samples.
* Prodesign R system demanded more time to shape the MB2 canals compared with Reciproc and produced lower change in volume of the entire canal compared with Mtwo.

Clinical Significance

Mechanized systems composed of conventional and M-wire files were able to explore the MB2 canal more easily, and M-Wire file shaped canals faster when compared with the more flexible CM-wire file. In addition, files with a .06 and .08 taper removed an excessive amount of dentin in the inner furcation area and were more prone to causing a strip-perforation in the coronal third.

Introduction:

The introduction of mechanized nickel-titanium (NiTi) instruments has made root canal preparation easier, safer, faster, and simultaneously respected and preserved the original anatomy of the canal (1–3). Heat treatment of raw NiTi alloys alters the microstructural phases (austenite, martensite and R-phases) enhancing their mechanical properties (4,5). During clinical use, the new files manufactured with M-wire and CM-wire technologies exhibit a martensite phase in their composition, while conventional NiTi alloy is essentially composed of an austenitic phase (1,4). The presence of the optimized microstructure of new heat-treated files has increased their flexibility and contributed to superior fatigue resistance when compared with the conventional alloy (4–7).

Profound knowledge of the complexities of the root canal system is of paramount importance for performing accurate root canal treatment. High prevalence (96%) of second mesiobuccal canal (MB2) is expected in maxillary first molars (8). The MB2 is frequently located under a thick dentin shelf, mesial to or directly in a line between the MB1 and the palatal orifices. The complex geometry of MB2 canals may present wide variability, including single or multiple canals, with isthmuses or anastomosis. Furthermore, this canal may be abruptly curved in different directions and present areas of calcification (9). Moreover, a thinner dentin wall in the furcation area, also named “danger zone” (10), with a reduced thickness of up to 33% compared with the mesial area should be shaped with extreme caution (11). This is an additional challenge to the shaping process.

Recently, a prospective clinical study introduced a new approach to negotiating and shaping the MB2 in maxillary molars, using a single-tapered reciprocating file system (12). Nevertheless, up to date, no study was found evaluating the performance of different NiTi alloys in negotiating and shaping MB2 canals in maxillary molars with regard to canal transportation/centering ability, changes in volume and the remaining dentin thickness in the coronal third.

Micro–computed tomography scanners (micro-CT) have been used as non-destructive, reproducible and a powerful technology for analyzing root canal geometry by matching reconstructed samples of preoperative and postoperative root canal images (3). This technology accurately measures the canal transportation (13–15), centering ability (13,16), remaining dentin thickness (2,17) and changes in volume (2,13,14,18).

Reciproc and Mtwo instruments have been widely used to prepare root canals. Recently, the Prodesign R - a new CM-Wire NiTi system - was launched by Easy (Easy Equipamentos Odontológicos, Brazil). The manufacturer claims that after the glide path procedure, a single reciprocating file can prepare the canal to reach the patency. Up to this point in time, there are no investigations in the literature evaluating the ability of Mtwo and Prodesign R to negotiate and shape MB2 canals.

Therefore, the primary goal of this study was to assess the influence of different NiTi alloys, with the use of a Micro-CT scanner, regarding the following aspects: transportation/centering ability, changes in volume, the number of specimens with a thickness of under 0.5 mm, and the remaining dentin thickness in the coronal third. The secondary goal was to evaluate the time consumed to negotiate, reach working length (WL) and shape the canal.

Materials and Methods

Sample selection

After approval from the Ethics Committee, (protocol: 1.173.071, CAAE 46767515.2.0000.5417), thirty maxillary first molars were selected according to the following criteria: intact roots, complete root formation, and absence of root canal treatment. The teeth were stored in individual labeled plastic vials containing 0.1% thymol solution until they were used.

All samples were scanned using micro-CT to enable standardization by selecting specimens with Vertucci type IV canal configuration (19). There was no restriction relative to the presence of apical curvature and the degree of narrowness of the root canal space, thus a total of 30 first maxillary molar teeth were included in this study.

The alpha-type error of 0.05, a beta power of 0.95, and a ratio of N2/N1 to 1 were also stipulated. A total of 8 samples per group were indicated as the ideal size required for noting significant differences. Ten samples per group were used because an additional 20% was calculated to compensate for possible accidents, such as instrument breakage that might lead to sample loss.

Micro-CT Analysis

Each tooth was scanned twice: before and after the instrumentation process. After being washed in running water for 24 hours, each tooth was dried and assembled on a custom attachment and scanned using a micro-CT system (SkyScan 1174v2; Bruker-microCT, Kontich, Belgium). The following acquisition parameters were used to capture the images: 50 kV, 800 mA, 0.80 step size rotation, 0.5 mm Al filter, and 19.7 mm voxel resolution. The same scanning parameters were kept for all specimens. For image reconstruction, the same parameters were used for each tooth after each scanning procedure, using dedicated software, NRecon (v1.6.4; SkyScan). After binarization, the region of interest was limited to the area involving the MB2 canal. Data Viewer software (Bruker-microCT) was used to pair all samples and standardize the same area of assessment. The Data Viewer and CTAan software programs (Bruker-microCT) were used to analyze the cross-sections and three-dimensional images. The cross-section analyses allowed calculation of the canal transportation, centering ability in both thirds and remaining dentin thickness in the coronal third towards the furcation area. The three-dimensional images were used to evaluate the apical and entire volume (mm^3) of the MB2 canal. For the purpose of establishing the volume, the MB2 canal was analyzed at 2 different levels: Apical third, between 1.0mm and 4.0mm short of the apex; and the entire length of canal, between 1.0mm short of the apex to the entrance of the canal orifice.

Root Canal Preparation

All previous restorative materials and caries were removed. After completing access opening, the MB2 canal was located with the aid of an E7D ultrasonic endodontic tip (Helse

Dental Technology, Santa Rosa de Viterbo, São Paulo, Brazil). A #47 endodontic probe was used to check its location and a size 10 K-file was inserted into the coronal third to guide the position for the next files to be used in canal. Irrigation was performed with 2.5% sodium hypochlorite (NaOCl) solution delivered with a 30-gauge Navitips needle (Ultradent Products Inc, South Jordan, UT). The working length was established when the file system being tested was visualized in the apical foramen at 8x magnification using a surgical microscope (DF Vasconcelos, São Paulo, Brazil). To standardize the time assessment, cases in which patency was not achieved after five attempts of the file failing to reach working length, the maximum depth of the file determined this point. In cases in which the file system tested was not visible at the apical foramen, the distance between that point and the apex was established and recorded by using CTan software (Bruker-micro CT). All samples that had a working length longer than 1 mm from the apex and exhibited file fracture were excluded. The canals with patency, or those with the working length between the apical foramen and 1 mm short of the apical foramen, were included in this study.

All experimental procedures were performed by one endodontist. Each instrument was used once and then discarded. Root canal preparation was performed in accordance with each system manufacturer's instructions. Furthermore, the working time was measured in seconds, with a digital chronometer, and set only when the files were active inside the canal.

Reciproc Group (REC)

In Group REC (n=10 teeth), canal preparation was performed using R25 Reciproc files (25/.08) (VDW, Munich, Germany) with the Reciproc program (150CCW/30CW) function of the VDW Silver electric motor.

Prodesign R (PDR)

In Group PDR (n=10 teeth), prior to shaping the root canals, a glide path was performed with a single Pathfile #1 (13, 0.02 taper), with the VDW Silver electric motor set at 300 rpm and 1.0 N/cm torque. ProDesign R files (Easy Equipamentos Odontológicos, Brazil) size 25/.06 taper were used in a reciprocating motion (330CW/30CCW) using the Endo Easy SI Basic electric motor (Easy Equipamentos Odontológicos, Brazil).

Mtwo Group (MO)

In Group MO (n=10 teeth), preparation was performed with the basic sequence of Mtwo rotary files composed of 4 instruments with different sizes: 10/.04 taper; 15/.05 taper;

20/.06 taper and 25/.06 taper. The files were used sequentially to prepare the canal to the full working length with the pre-set program function of the VDW Silver electric motor.

When the mechanical preparation was considered complete, all canals were irrigated with 5mL of 2.5% NaOCl and flushed with 5mL of 17% EDTA for 3 minutes to remove the smear layer. The canals were rinsed with 5 mL of saline solution and dried with paper points (Dentsply, Tulsa). After root canal preparation, Micro-CT scan images were acquired once again as previously described.

Root Canal Transportation

One calibrated examiner, blinded to the file system used to prepare the canals, evaluated the cross-section images obtained before and after instrumentation, with the use of Data Viewer software (Bruker-microCT) to assess and measure the root canal transportation.

The root canal transportation assessment in the apical third and coronal third was calculated in millimeters using the formula ([X1-X2] - [Y1-Y2]) according to Gambill et al (16). X1 and X2 meant the shortest distance from the edge of uninstrumented and instrumented MB2 canal respectively, to the mesial portion of the mesiobuccal root. Y1 and Y2 meant the shortest distance from the edge of uninstrumented and instrumented MB2 canal, respectively, to the distal portion of the mesiobuccal root. For this analysis, a positive value meant that transportation occurred in the mesial direction, and a negative value indicated that transportation occurred in the distal direction, which was towards the furcation area ("danger-zone"). A value equal to zero meant that no transportation had occurred.

Centering ability

The mean centering percentage, which measured the ability of the file to continue on a centered line, was calculated in the apical and furcation areas to assess the root canal transportation, found by using the following formula: (X1-X2)/(Y1-Y2) or (Y1-Y2)/ (X1-X2) (16). The lower value was considered to be the numerator of the formula. With this formula, a result of 1 indicated perfect centering ability.

Remaining Dentin Thickness (RDT) and the Number of specimens with a thickness of under 0.5 millimeters

The amount of dentin removed towards the "danger zone" in the coronal third was determined by subtracting the uninstrumented distal dentin thickness from the instrumented distal dentin thickness [Y1-Y2]. The measurement of thickness under 0.5 mm (20) was used as the parameter to consider excessive dentin removal on the distal side in the danger zone.

Statistical Analysis

The two-dimensional and three-dimensional parameters, and the working time were compared between groups using the Kruskal-Wallis and Dunn Multiple Comparison tests within groups (P< 0.05). The specimens with a remaining dentin wall less than 0.5 mm thick on the distal side were statistically evaluated by Chi-square (X^2) test (P< 0.05).

Results

The canal transportation and centering ability values measured at the coronal and apical levels are listed in Table 1. There were no statistical differences among the three groups. The patterns of canal transportation and the remaining dentin thickness in all groups are represented in images of matching axial reconstructions (Image 1). Discrepancies in the volume before and after canal shaping are described in Table 2. There were no statistical differences among the groups. The remaining dentin thickness after preparation, the number of specimens with a thickness of less than 0.5 mm in the coronal third; the working time mean values, and the percentage of negotiable canals and failures are shown in Table 3. Excessive coronal preparation was observed in 5 specimens (55%) of Group REC, in 3 specimens (37.5%) of samples in Group PDR and 6 teeth (66.6%) in Group MO. Group PDR demanded significantly more time for preparation when compared with Group REC (P<0.05), while no statistical differences in time preparation were found between Groups REC/MO and PDR/MO.

Two types of failures were observed: file breakage and perforation. Groups MO and PDR showed file separation in 10% of samples for each group. Groups MO and REC showed that perforation was caused in the coronal third in 10% of samples for each group (Figure1.g and i). In one sample of Group REC and Group PDR the acceptable working length established for this study could not be reached and they were removed. Overall, 9 samples of REC, 8 samples of PDR and 9 samples of MO were evaluated by Micro-CT.

Discussion

In the present study, maxillary first molars with Vertucci type IV classification were chosen for the purpose of isolating and reducing the influence of other complications and allowing better standardization of the samples (21). Thus, the mesial and distal areas could be measured accurately to evaluate the canal transportation, centering ability and remaining dentin thickness. A previous clinical study showed a new approach to negotiating and preparing the MB2 canal using a single reciprocating tapered file composed of M-wire technology (12). In the present study one conventional (MO) and two heat-treated M-Wire (REC) / CM-wire (PDR) files were evaluated regarding their ability to properly negotiate and shape MB2 canals. Two separate thirds of the canal (apical and coronal) were chosen due to their (MB2) peculiar anatomy. These areas have a thin dentin wall, especially towards the furcation area, also known as the "danger-zone". This area is prone to perforations if not properly managed (10,11). The micro-CT technology has proven to be an effective and accurate methodology to assess the parameters evaluated in this study (2,13,14,17), in addition to being a non-destructive and reproducible methodology.

Root canal preparation was performed in accordance with each file system manufacturer's instructions. All three groups had an apical enlargement to a size 25, however, the taper varied in Group REC (.08) when compared with Groups MO and PDR (.06). Files with larger taper are presumed to not to be ideal for reaching the full WL in curved and/or constricted canals. However, our findings contradict this supposition, since the MO and REC instruments had similar performance when negotiating and shaping the canal (60%). Our results are similar to those of other studies that also used the Reciproc files without glide path (12,22). Additionally, glide paths have been recommended to allow the NiTi files to shape the canals by using both rotary and reciprocating motion in a safer manner (23). Nevertheless, achieving a glide path prior to using the Reciproc instruments is not mandatory in the majority of cases, according to a recent study (12). However, the authors of the present study performed a pilot study using the PDR file (CM wire) and noted that this file could not progress towards the apical portion without creating a glide path prior to shaping. Thus, for Group PDR a Pathfile 13.02 was used. The results of inability to reach patency of the MB2 canal may be explained by the great variability in the MB2 canal pathway, as this canal turns sharply toward the buccal or palatal side (24), thus making it impossible to achieve patency. Furthermore, the CM-wire file, such as Prodesign R, may require a glide path procedure prior to root canal preparation because its flexibility is superior to that of the conventional NiTi (4) and it has lower torsional strength than both conventional NiTi-Wire and M-Wire instruments (25). Thus, the performance of CM-wire in complex anatomy, as seen in the MB2 canal, could be subject to more difficulty while attempting to reach full working length.

In all three groups, canal preparation tended to transport towards the distal area (furcation) in the coronal sections and toward the outside of the mesial region in the apical sections, as previously described in numerous micro-CT studies (2,10,14,15,18). Thus, in curved canals, a mesial deviation in the apical third (14,15,18) and a distal deviation at the coronal third (15,16) is expected. In all sections evaluated there was no significant difference in canal transportation in the apical and the coronal thirds between the groups. Similarly to our results, a recent study(17) showed the tendency of CM Wire (Protaper Gold) and M-Wire (Protaper Next) to show less canal transportation and maintain dentin thickness compared with a conventional NiTi file (Protaper Universal). Although no significant differences were observed relative to canal transportation between the experimental groups, our results showed less canal transportation in the apical third with the more tapered file in REC 25/.08, suggesting that the treated NiTi alloy plays an important role in the flexibility of the file (4). On the other hand, other studies have shown good ability of Mtwo files to keep the original curvature in molars (26).

The measurement of 0.5 mm of remaining dentin has previously been reported to evaluate narrow and wide roots (20). However, the mean value of the measurements in coronal preparation seemed to be a safe standard to prepare the canal with the three systems (Table.3). In 66% (6 samples) of the group, the coronal thickness remaining for conventional NiTi (Group MO) exhibited an excessive enlargement, followed by 55% (5 samples) for Group REC. Three samples in CM-wire treated NiTi file Group (PDR) showed the lowest percentage (37.5%). The remaining dentin in Group PDR suggested that this type of NiTi (CM-wire) may reduce the activity of the file toward the furcation side compared with the other files tested. Usually, when analyzing the coronal third, a tapered file has a bigger core diameter with increased stiffness, irrespective of the type of alloy (27). However, our results suggested that even larger files may have reduced action on the dentin wall. This may occur because the CM- wire file (PDR) is in its martensite form in clinical situations, which results in a softer material that can be easily deformed (4). Therefore, the behavior of the files should also be considered when analyzing the preoperative canal geometry(14) to avoid potential mishaps during instrumentation. Apart from tapered files (taper >.06), the ledge of dentin at the canal entrance may force the file toward the distal wall, causing excess dentin removal in a danger zone (11) and leading to perforation. Moreover, the influence of different preflaring techniques in narrow canals may explain the lowest percentage of excessive coronal preparation (27%) in Group MO in the previous study (20) compared with our results (66%).

The increased flexibility of CM-Wire alloy endodontic files is characterized by stabilized martensite under conditions of clinical use (4). In a clinical situation, when preparing curved canals, the martensite crystal phase deforms easily at fairly low pressure when compared with the austenite phase (1). In addition, this feature may alter the original shape of the file, reducing the effectiveness of the cutting-blades. This may explain the performance of Group PDR in the present study. This group showed the lowest cutting efficiency, lower canal transportation, less increase in volume, higher centering ability and longer preparation time when compared with Groups REC and MO. Furthermore, CM-Wire files requires higher reciprocating angles in reciprocating motion and higher speed in rotary motion to compensate the lower cutting efficiency when compared with other alloys (28). In contrast, the conventional NiTi file (Mtwo) is used in the austenite state, while M-Wire (REC) alloys contain martensite in their composition(1,4). The austenite content characterizes a stronger and harder alloy (29) and this may benefit the negotiability of Groups MO and REC groups in reaching the FWL more easily. These groups also required less preparation time than PDR files with a statistically significant difference in working time between Groups REC and PDR specifically.

The similarity of design and size of files in the REC and MO systems showed great dentin cutting ability (26,30), with less preparation time in curved canals (28,31) and rise in canal volume in curved canals (2,15). The effect of the alloy increased flexibility and reduced torsional strength in PDR files (25). However, the distinctly reduced change in entire volume for PDR in comparison with MO may be due to decreased ability to cut dentin and the reduced cross-section of the PDR file. Recently, an in vitro study using scanning electron microscopy evaluation showed the smallest cross-section area for Prodesign R (98.521 μm^2) compared with Reciproc (112.686 μm^2) (25). Further studies should be considered to evaluate the hybridization of small tapered (.02/.04) reciprocating and rotary files to negotiate and prepare canals more evenly in order to avoid over-enlargement in coronal thirds of narrow canals (20). Additionally, negotiating constricted canals increased torsional failure when binding of the file occurred within the canal (32). Although the martensite phase has been associated with notable flexural fatigue resistance (4), M-wire alloy with a lower amount of martensite in its composition, had superior resistance in torsional strength to failure compared with CM-Wire files (7,25). This may explain the absence of failures in Group REC in our study.

Conclusion:

According to the results of this ex-vivo study, all three NiTi files instrumented the MB2 canals in a similar manner with regard to transportation, centering ability and increase in apical volume. M-wire files explored the MB2 canals more easily and shaped them faster when compared with the more flexible CM-wire file. The .06 and .08 tapered files removed more dentin in the furcation area and were more prone to cause perforation in the coronal third.

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Figure 1. Representative images of matching axial reconstructions for Groups Reciproc. Prodesign R and Mtwo, in the coronal third, apical third, and remaining dentin thickness after preparation. Red indicates the preoperative canal, and green, the postoperative canal.

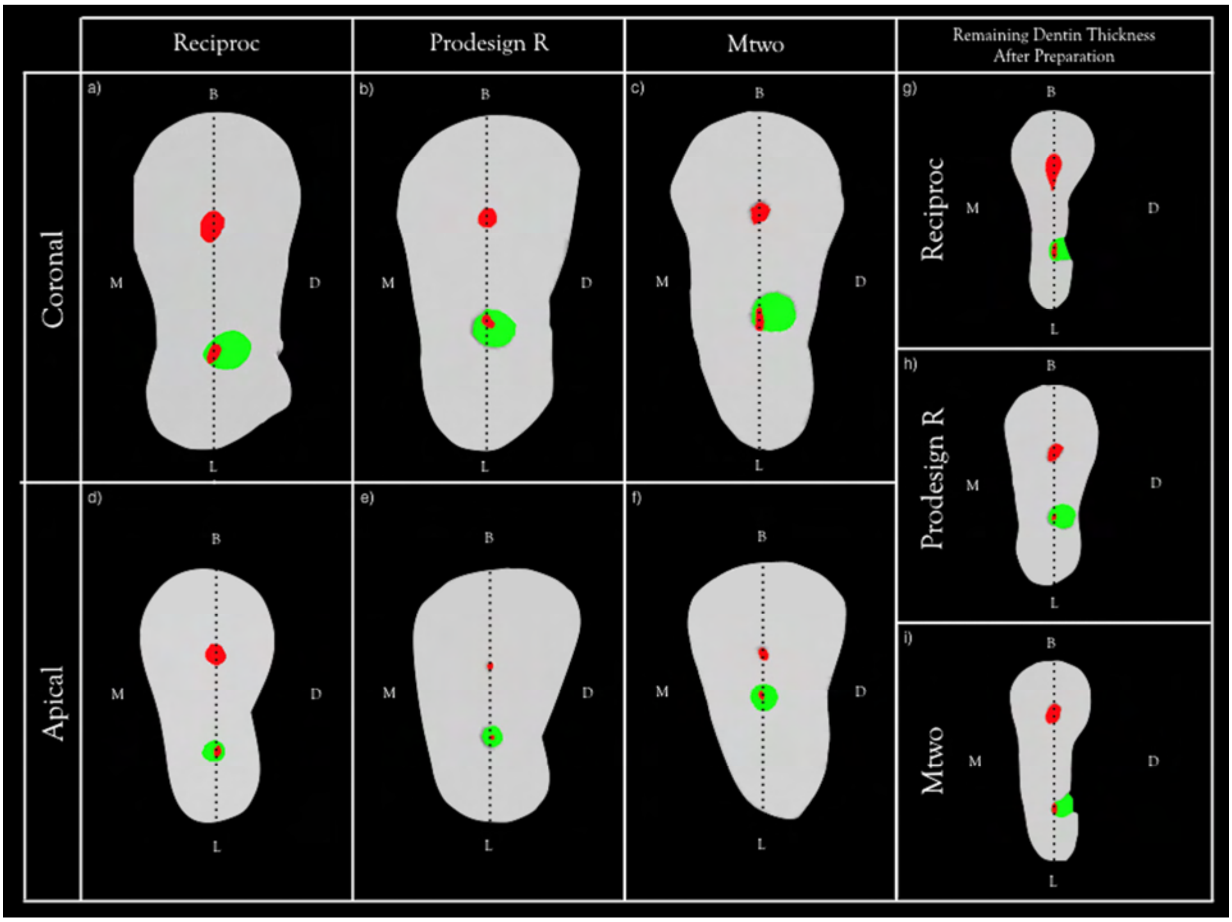

Table 1. Mean (X) and standard deviation (SD) for the canal transportation and centering ability in the four millimeters of the apical and coronal thirds of the MB2 canals in maxillary first molars evaluated after preparation with the instruments analyzed

Instruments	N	Thirds	Distance to the Apex or furcation area (mm)	Canal transportation *(mm) X±SD	Mean Canal Transportation in the four mm Assessed X±SD	Centering ability** X±SD	Mean Centering ability in the four mm Assessed X±SD
Reciproc	9	Apical	1	0.07 ± 0.11[a]	0.06 ± 0.04	0.30 ± 0.36[a]	0.37± 0.07
			2	0.11 ± 0.15[b]		0.35 ± 0.31[b]	
			3	0.06 ± 0.16[c]		0.46 ± 0.31[c]	
			4	0.01 ±0.28[d]		0.38 ± 0.20[d]	
		Coronal	4	-0.13 ± 0.32[e]	-0.35± 017	0.47 ± 0.27[e]	0.28± 0.13
			3	-0.32 ± 0.30[f]		0.25 ± 0.20[f]	
			2	-0.45± 0.22[g]		0.22 ± 0.18[g]	
			1	-0.51 ± 0.26[h]		0.19 ± 0.27[h]	
Prodesign R	8	Apical	1	-0.02 ± 0.14[a]	0.02 ± 0.03	0.44 ± 0.27[a]	0.54± 0.09
			2	0.001± 0.08[b]		0.64 ± 0.24[b]	
			3	0.06 ± 0.18[c]		0.57 ± 0.35[c]	
			4	0.01 ± 0.18[d]		0.49 ± 0.25[d]	
		Coronal	4	0.03 ± 0.13[e]	-0.16± 0.19	0.45 ± 0.25[e]	0.36± 0.12
			3	-0.03 ± 0.26[f]		0.44 ± 0.32[f]	
			2	-0.27 ± 0.19[g]		0.34 ± 0.25[g]	
			1	-0.36 ± 0.14[h]		0.19 ± 0.19[h]	
Mtwo	9	Apical	1	0.09 ± 0.37[a]	0.09 ± 0.03	0.32 ± 0.52[a]	0.46± 0.15
			2	0.05 ± 0.14[b]		0.36 ± 0.25[b]	
			3	0.12 ± 0.14[c]		0.49 ± 0.34[c]	
			4	0.10 ± 0.15[d]		0.66 ± 0.40[d]	
		Coronal	4	0.02 ± 0.23[e]	-0.30 ± 0.22	0.48 ± 0.38[e]	0.36± 0.10
			3	-0.29 ± 0.20[f]		0.40 ± 0.34[f]	
			2	-0.44 ± 0.27[g]		0.27 ± 0.26[g]	
			1	-0.47 ± 0.30[h]		0.27 ± 0.30[h]	

*Positive values indicate transportation towards the mesial side that is opposite to the furcation area in MB2 canal; negative values indicate transportation towards the distal side (furcation area) in MB2 canal. Result zero for transportation indicates that no transportation occurred.

**Centering ratio: number 1 indicates perfect centering ability. The closer the result is to zero, the worse the ability of the instrument to remain centered.

***No statistical differences were found in the intergroup comparison at the same level (Kruskal-Wallis and Dunn. P>0.05).

Table 2. Mean (X) and standard deviation (SD) for the volumes (mm^3) of the entire canal and apical third before and after the use of the files tested and the volume (mm^3) of the dentin removed.

Instruments	N	Area analyzed*	Initial volume (mm^3)* X± SD	Final volume (mm^3)* X± SD	Volume of dentin removed (mm^3)** X± SD
Reciproc	9	Entire canal	0.64 ± 0.44^{a}	2.62 ± 1.62^{Aa}	1.99 ± 1.21^{a}
	9	Apical third	0.19 ± 0.18^{b}	0.72 ± 0.26^{B}	0.53 ± 0.18^{b}
Prodesign R	8	Entire canal	0.35 ± 0.21^{a}	1.37 ± 0.49^{a}	1.02 ± 0.45^{a}
	8	Apical third	0.14 ± 0.09^{b}	0.49 ± 0.25^{B}	0.36 ± 0.19^{b}
Mtwo	9	Entire canal	0.78 ± 0.52^{a}	2.51 ± 1.00^{A}	1.73 ± 0.59^{a}
	9	Apical third	0.18 ± 0.19^{b}	0.64 ± 0.48^{B}	0.47 ± 0.32^{b}

* Mean volume in apical third was calculated from 1 millimeter short of the apex to 4 millimeters distant from the apex; mean volume in all thirds was calculated from the apical foramen to the coronal third (furcation area).

**Volume of dentin removed was calculated by subtracting the initial (uninstrumented) canal volume from the final (instrumented) canal volume.

***Same superscript letters indicated no statistical differences in intergroup comparison (Kruskal-Wallis test and the Dunn Multiple Comparison Test. P> 0.05).

Table 3: The mean (X) ± standard deviation (SD) of the anatomic root thickness, remaining dentin thickness (mm) after preparation, removal of distal dentin wall (mm) in the coronal third and the number of samples of remaining dentin thickness of under 0.5 (mm); working time (s) and percentage of negotiable canals and failures in MB2 canals of maxillary first molars in the three groups

Group	N	Anatomical root thickness (mm) [Y1] X±SD	Remaining Dentin Thickness* (RDT) (mm) [Y2] X±SD	Removal of distal dentin wall (mm) [Y1-Y2] X±SD	Number of specimens with thickness of under 0.5 millimeters* (%)	Working time (s) X±SD **	Negotiable canals (n/total) (%)	Failures	
								Fracture (n/total) (%)	Perforation (n/total) (%)
Reciproc	9	1.09 ±0.08	0.62 ± 0.03^{A}	0.47 ± 0.10	$5\ (55\%)^{A}$	127.9 ± 27.7^{A}	6/10 (60%)	0/10 (0%)	1/10 (10%)
Prodesign R	8	0.95 ±0.11	0.67 ± 0.04^{A}	0.28 ± 0.14	$3\ (37.5\ \%)^{A}$	219.5 ± 22.4^{B}	4/10 (40%)	1/10 (10%)	0/10 (0%)
Mtwo	9	1.06 ±0.10	0.61 ± 0.13^{A}	0.45 ± 0.16	$6\ (66.6\%)^{A}$	164.2 ± 42.0^{AB}	6/10 (60%)	1/10 (10%)	1/10 (10%)

Y1: the thickness measurement of the distal wall in the coronal third before shaping procedure.

Y2: the distal thickness measurement in the coronal third after shaping procedure.

*Same superscript letters indicated no intergroup statistical differences (Chi-square Test. P>0.05).

**Same superscript letters indicated no statistical differences in intergroup comparison (Kruskal-Wallis test and the Dunn Multiple Comparison Test. P>0.05).

2.2 ARTICLE 2

Evaluation of the larger apical preparation in mesiobuccal and distobuccal canals of maxillary molars prepared with Reciproc, Hyflex CM and Twisted file adaptive systems: a micro-computed tomography study

Abstract

Introduction: The aim of this study was to understand the role of new treated NiTi alloy made from M-Wire, CM-Wire and R-phase NiTi alloys, in larger apical preparation of the mesiobuccal (MB) and distobuccal canal (DB) of maxillary molars, and simultaneously evaluate these preparation procedures by means of micro-computed tomographic (micro-CT) imaging.

Methods: A total of 45 mesiobuccal (MB) roots and distobuccal (DB) roots of extracted maxillary molars were chosen according to the following criteria: the MB canal exhibiting curvatures according to the Weine classification in the 20-30 degree range and the DB canal presenting the 0-5 degree range. These teeth were randomly distributed into three groups, Reciproc (REC); Hyflex CM (HF) and Twisted file Adaptive (TFA). All groups in which REC and HF instruments were used, were instrumented to 40/.06 with the respective file system. The TFA subgroups were instrumented to 35/.04. The following parameters were evaluated: canal transportation (CT), centering ability (CA), change in volume (VC), Dentin Thickness (DT) and shaping time (ST). All parameters were statistically compared using the Kruskal-Wallis and Dunn Multiple comparison tests within groups with a significance level of 5%.

Results: In MB and DB canals, the canal transportation showed a tendency towards inner curvature in the apical third, while in the coronal third, the trend was towards the outer curve. There was no difference in apical transportation in the first apical millimeters for both types of canals. In MB canals, at 3 and 4 mm, the values for Reciproc were significantly lower than those of Hyflex CM($P<0.05$). In DB canals, at 2 and 4 mm, the Reciproc values were substantially higher than those of TFA ($P<0.05$). In both canals, there was no statistically significant difference between the three systems relative to centering ability in the apical third and the remaining dentin thickness (RDT). For DB canals, there was no significant difference in shaping time, but in MB canals, working with TFA was faster than with than Reciproc and Hyflex. The initial changes in volume (apical/entire) after canal preparation were statistically

significant within groups in MB and DB canals for percentage and volume of dentin removed. TFA had the lowest values for the apical and the entire volumes of dentin removed in both canals compared with Reciproc and Hyflex ($P < 0.05$). TFA had the lowest percentage of dentin removed in the entire MB canal, and in the apical and the entire volume removed from DB canal.

Conclusions: The heat treated NiTi alloy systems used for larger apical preparation evenly maintained the morphology of MB and DB canals of maxillary molars. In shaping procedures, the larger apical preparation produced slight canal transportation with no evidence of significant preparation errors. However, these variations may not be clinically significant. TFA was swifter for preparing the MB canal and produced fewer changes in volume parameters. TFA system was able to preserve the original canal anatomy with less canal transportation than Reciproc and Hyflex CM systems.

Keywords:
micro–computed tomographic imaging, root canal transportation, Reciprocating systems, rotary systems, controlled memory wire.

Clinical Significance:
The heat treated NiTi alloy systems used for larger apical preparation evenly maintained the morphology of MB and DB canals of maxillary molars. The largest size preparation significantly increased the final and volume of dentin removed from the MB and DB canals.

Highlights:

- All systems evaluated produced canal preparation with no significant apical transportation in the first millimeter.
- The larger apical preparation kept the canals evenly centered in the apical third of both types of canals, and in the coronal third of MB canal.
- TFA used for preparation of MB canals was faster than using the Reciproc and Hyflex CM systems.
- TFA showed the lowest percentage values of apical and entire volume of dentin removed and the volume of dentin removed in apical from both types of canals.

Introduction:

An essential aspect for successful endodontic therapy is thorough cleaning and shaping of the root canal (1), preserving the original canal axis and anatomical structures(2). Respecting the canal anatomy is especially challenging in the apical thirds of curved canals (2,3) and thinner areas in the coronal third denominated the danger zone(4). These areas are prone to some shaping errors, such as stripping and perforation (2,5) as mishaps of this type may weaken the dentin structure (3,6), and compromising the prognosis of endodontic treatment (7).

In Endodontics, the development of new treated NiTi alloys and instrument designs in the last decade has favored strategy innovations that have made the shaping procedure safer and more centered(8). By simplifying the filing technique with a single or lower number of files, canal preparation has been extensively performed with the use of more tapered instruments(8). These new files are produced with a heat treatment manufacturing process that has enhanced their mechanical properties, such more flexibility and greater fatigue resistance (9). The new thermally treated NiTi alloys include the M-Wire alloy (10,11), CM wire–alloy (controlled memory) (9) and R-phase alloy(12). The M-Wire, CM-Wire and R-Phase NiTi alloys are represented commercially by Reciproc (VDW, Munich, Germany), Hyflex CM (Coltene, Cuyahoga Falls, OH, USA) and twisted file Adaptive (SybronEndo, Orange, CA) systems, respectively. The instruments manufactured from M-Wire and CM-Wire alloys have shown superior cyclic fatigue resistance compared with those made of conventional superelastic wire, with up to 390% (13) and 300-800%(9) more resistance to cyclic fatigue, respectively. Furthermore, a new R-Phase NiTi file (K3XF3) has shown better flexibility and cyclic fatigue resistance when compared with M-Wire files (14).

At present, X-ray micro-computed tomography is a reliable, non-destructive and reproducible methodology that has been used for investigating the shaping abilities of endodontic file systems(15–19). Limited studies have compared the effect of the new thermally treated NiTi systems on the shaping ability and apical transportation in canals prepared with larger apical preparation (19). These larger apical preparation sizes have potential to reduce the number of intracanal microorganisms(2), improve the antimicrobial effectiveness of irrigants and disinfection (20) and clean the canal more efficiently in the apical third (21). Moreover, larger apical preparation (0.40) has previously been evaluated in the danger zone of mesial root of mandibular molars, and was indicated as being safe as regards dentin thickness (19). However, for maxillary molars, this information is still lacking and it continues to be of concern. Thus, the purpose of this study was to compare the performance relative to shaping ability of these three heat-treated NiTi systems in larger apical preparations in mesiobuccal and distobuccal canals of maxillary molars, by using micro-computed tomographic (micro-CT) analysis.

Material and Methods:

Sample Selection:

In this experiment, mesiobuccal and distobuccal canals of forty-five maxillary molars with mature apices, which were stored in 0.1% thymol solution, were selected, after their use was approved by the Ethics Committee, (protocol: 1.173.071, CAAE 46767515.2.0000.5417). The teeth were cleaned with periodontal curettes to remove soft tissue, and radiographs were taken. Canal curvatures were measured according to the Weine technique (22). Mesiobuccal canal in the 20-30^{o} range and distobuccal canal exhibiting the 0-5 ^{o} range were included in this study. Before root canal preparation, conventional access openings were made with #4 round and Endo Z burs (Dentsply Maillefer) in each tooth. The working length (WL) was established by introducing a size 10 K-file (Dentsply Maillefer) until it could be detected through the apical foramen, after which 1 mm was subtracted.

Root Canal Preparation:

According to above-mentioned criteria, 45 maxillary molars were chosen and distributed equally into three groups: two Reciproc files [VDW, Munich, Germany], Hyflex CM-files [Coltene/Whaledent, INC, Cuyahoga Falls, OH] and TFA [SybronEndo, Orange, CA] (n = 15). The MB and DB canals were prepared with Reciproc (R25 and R40); and Hyflex CM (HF 25/.06 and HF 40/.06) to a size 40.06. For Twisted File Adaptive, both canals were prepared to 35.04 with the SM series [SM1 (20/.04); SM2 (25/.06) and SM3 (35.04)]. The shaping time was recorded for each group. All canals were soaked with a 30-gauge needle syringe with 10 ml of 2.5% NaOCl. When the mechanical preparation was considered complete, all canals were irrigated with 5mL of 2.5% NaOCl and flushed with 5mL of 17% EDTA for 3 minutes to remove the smear layer. The canals were rinsed with 5 mL of saline solution and dried with paper points (Dentsply, Tulsa), then specimens were micro-scanned for post-treatment analysis. The canal transportation, centering ability, the dentin thickness, volume of canals and the shaping time were recorded to assess the differences between the three groups.

Micro-CT procedures

Micro-CT images were captured before and after canal, preparation using Micro-CT System (SkyScan 1174v2; Bruker-microCT, Kontich, Belgium) with the following parameters: 50 kV, 800 mA, 0.8 step size rotation, filter 0.05 mm Aluminum, 19.7 nm voxel size and 1024x1304 resolution. The data were developed by a dedicated reconstruction software (NRecon v.1.6.3; Bruker-microCT), and the CTan software (Bruker-microCT). Data Viewer software (Bruker-microCT) was used for pairing and standardizing the same region of the samples for assessments.

Measurement of Root Canal Transportation

Transportation was measured in the first four millimeters in the apical and coronal thirds. Cross-sectional images collected before and after instrumentation, analyzed with Data Viewer software (Bruker-microCT), were used to measure the root canal transportation according to the following formula suggested by Gambill et al.(23): [X1-X2] - [Y1-Y2]. The canals were measured on the mesial and distal sides, before and after instrumentation. For mesial side measurements, the X1 was the shortest distance from the outside of the curved root to the periphery of the uninstrumented canal, while X2 was the shortest distance from the outside (mesial side) of the curved root to the periphery of the instrumented canal. For distal measurements, Y1 was the shortest distance from the inside (distal side) of the curved root to the periphery of the uninstrumented canal, while Y2 was the shortest distance from the inside (distal side) of the curved root to the periphery of the instrumented canal.

Originally, Gambil et al. (23) proposed to measure the thicker side in the mesial position and then subtract the value of the thinner side in the distal position, before and after instrumentation. Because of the distinct thickness in the distobuccal root, the equation was adapted for the distobuccal root and the formula proposed was: (Y1-Y2)-(X1-X2). A result of 0 obtained by the canal transportation formula indicated no canal transportation. A positive value indicated that transportation occurred opposite to furcation area (inner curve); while the negative value showed that transportation occurred towards the furcation area (outer curve).

Measurement of Centering Ability

The X1, Y1, X2, Y2 measurements in apical third and coronal third were used to evaluate the centering ability, according to the equation suggested by Gambil (Gambill, Alder, and del Rio 1996): (X1-X2)/(Y1-Y2) or (Y1-Y2)/ (X1-X2). The lower value was considered the numerator of the formula. With this formula, a result of 1 indicated perfect centering ability.

Dentin Thickness Evaluation

The anatomical root thickness of the mesial and distal wall in the coronal and apical thirds was represented by the measurements of X1 and Y1, respectively. After canal preparation, the values of Remaining of Dentin Thickness on mesial and distal walls were represented by the measurements of X2 and Y2, respectively. The amount of dentin removed towards the "danger zone" coronally and apically was defined by subtracting the thicker dentin thickness from the thinner dentin thickness before and after instrumentation. The following equations were applied to the mesial and distal sides, respectively: [X2-X1] and [Y1-Y2].

Measurement of Root Canal Volume

With the aid of CTAn v.1.12 software (Bruker-microCT), a task list in the program was used to evaluate the values of apical and entire volumes (mm^3) of MB and DB canals. For each sample, these canal parameters were assessed at two levels: Apical third, between 1.0 and 4.0mm short of the apex; and Coronal third, between 1.0 and 4.0mm under the entrance of the canal, and entire canal (volume). The canal volumes were measured before and after canal shaping, and the changes in volume were recorded.

Shaping Time:

The shaping time was measured in seconds with a digital chronometer, set only when the files were rotating/reciprocating inside the canal, and recorded.

Statistical Analysis

The parameters of root canal transportation, centering ability, Dentin Thickness, changes in volume and shaping time were compared among the groups, by using the Kruskal-Wallis and Dunn Multiple comparison tests within groups ($P < 0.05$).

Results:

Table 1 shows the statistical analysis of post-instrumentation apical and canal transportation, centering ability and shaping time. In MB and DB canals, the canal transportation tended towards inner curvature in the coronal third, while in the apical third the trend was towards the outer curve. There was no statistical difference in the first apical millimeter for apical transportation in the two canals ($P>0.05$). There was no statistically significant difference among three systems for the centering ability in the apical third in the two canals. There was no difference in apical transportation in the first apical millimeters for the two canals. In MB canal, at 3 and 4 mm, Reciproc showed significantly lower values than Hyflex CM ($P<0.05$). In The DB canal, at 2 and 4 mm, Reciproc values were substantially higher than those of TFA ($P<0.05$). For the coronal third in the two canals, all systems transported in some levels, but the centering ability was not significantly different ($P>0.05$), except for TFA which had the higher centering ability at the 4 mm in the DB canal ($P<0.05$). For DB canal, there was no significant difference in shaping time ($P>0.05$), but in MB canal, working with Group TFA was swifter than with Reciproc and Hyflex ($P<0.05$).

Table 2 shows the statistical analysis for all volume parameters evaluated. In MB and DB canals, within groups the initial changes in volume (apical/entire) after canal preparation were statistically significant for percentage and volume of dentin removed ($P<0.05$). TFA showed the lowest values for the apical and the entire volumes of dentin removed in the two canals compared with Reciproc and Hyflex ($P<0.05$). TFA had the lowest percentage of dentin removed in the entire MB canal, in the apical and the entire volume of DB canal ($P< 0.05$).

The remaining dentin thickness and anatomical dentin thickness on the mesial and distal sides in the two canals did not differ statistically before and after canal preparation with the REC, HF and TFA systems ($P>0.05$). Table 3 shows the pre- and post- instrumentation statistics of initial volumes, final volumes, volume of dentin removed and the percentage of the dentin removed in the coronal and apical thirds analysis for the two canals.

A 3D visualization of a root canal shaped with Reciproc, HyflexCM and TFA and 2D cross sections are displayed in Figure 1.

Discussion:

This article assessed larger apical preparations performed in the coronal third (danger zone) and apical third, with regard to canal transportation, centering ability, dentin thickness, change in volume and shaping time to prepare the buccal roots canals of maxillary molars with use of the following systems: Reciproc (M-Wire reciprocating file), Hyflex CM (CM-rotary file) and TFA [R-phase combined motion (rotary/reciprocating].

Micro-computed technology has proved to be an adequate technology, because it is a non-invasive and reproducible method for two and three-dimensional evaluations of root canal systems(15–17,19,24). The methodology proposed for DB canal evaluation in this study was a modified form of the original formula (23). The purpose of this procedure was to equalize the parameters of canal transportation in multi-rooted teeth evaluated in this study. The modification was made, because the mesial side (X) represented the thinner side of the DB canal, and was necessary to avoid mistaken interpretations of the signs indicating the side of transportation. Some variables in this experimental design could not be isolated, such as the heat manufacturing process, the number of files used, the cross-section of the files and movement kinematics, because they belong to the manufacturers.

The main result was that there were no significant differences observed in the first apical millimeter for canal transportation and no significant differences in centering ability when using the Reciproc, Hyflex CM and TFA systems in MB and DB canals. The higher degree of flexibility of the Heat treated NiTi alloy files used in the two canals may explain the beneficial results in the apical thirds(9), particularly in the first apical millimeter. From that point on, specifically starting at 2 mm, the differences in apical and coronal transportation could be attributed to the effect of the dissimilarities in the cross-sectional design among the instruments. The Twisted File Adaptive system has an equilateral triangular cross-section, Reciproc has an S-shaped cross-section design with two sharp cutting edges (25) and Hyflex CM has a slightly convex triangular cross-section (26). An *in vitro* study revealed discrepancies at 3mm between Reciproc (25/.08) and TFA (25/.08) instruments. The cross-sectional area of Twisted File Adaptive (approximately 24.491 μm^2) is smaller than that of

Reciproc (approximately 129.136 μm^2) (27); these dissimilarities in cross section may explain the variations found in the volume, shaping time and canal transportation analysis.

Reports have stated that a file would become stiffer if its core diameter were increased, irrespective of the type of alloy (CM-wire, M-wire or R-phase)(3), thus explaining our results regarding the transportation found in the coronal and apical thirds evaluated. Some data from other studies were in agreement with ours, indicating that TFA with a traditional apical size produced less canal transportation compared with Reciproc (18,28). These authors (18,28) attributed the best performance of TFA system to the adaptive motion associated with the best flexibility of R-phase file (29). In addition, the evaluation of the changes in volume of similar studies have indicated that Reciproc (17,18) produced higher values of changes in volume compared with TFA (17,18). A similar study (17) found no difference in the volume produced in mesial canals of mandibular molars prepared with Hyflex CM(25/.08), Reciproc (25/08) and TFA (25/.08). Those authors (17) explained the difference between their results relative to the changes in volume, when compared with Gergi et al 2015(18), by attributing the reliability of their results to the similarity of the files tested, distribution of the samples, and tridimensional similarities in the sample.

The Reciproc and Hyflex CM produced slight apical canal transportation, confirmed in other studies (17,18,30) with the traditional apical size(#25). These instruments - Reciproc (31) and Hyflex CM (32) (33) - have been associated with greater cutting efficiency, which explains the higher mean transportation values in our coronal and apical transportation results. In this study, the Hyflex CM rotary system had the slightly higher value of canal transportation in the apical third and significant coronal transportation value in the DB canal. Reports have indicated that the spirals of Hyflex CM were deformed (unwound) in at least 80% (34) or 95%(35) of the instruments and this may have contributed to the pattern of apical transportation. For coronal transportation, the main reason for the highest value may be due to the continuous taper of the file starting at the tip and continuing through the shaft. Similar results observed when using large sized taper files in an acrylic block with a simulated canal that had a high degree of curvature (45º) were reported to have caused straightening at the beginning of the canal curvature (36). Our results of apical transportation at 4 mm confirmed this tendency, especially for the less flexible file (Reciproc), demonstrating the role of the NiTi alloy selected. Clinically, this behavior may be harmful in the preparation of flattened canals or those with higher degrees of curvature.

Larger apical preparations with tapered file systems in the apical and coronal thirds demonstrated that slight canal transportation occurred in the all groups, but preserved the remaining thickness of dentin on the mesial and distal sides of apical and coronal thirds (Figure 1). The measurements of remaining dentin thickness were over 0.3 mm indicated by LIM(37). Similarly to our results, in mandibular molars, the apical size preparation (#40) has previously been indicated as not being harmful to the remaining dentin in the apical thirds and danger zone (19). Previous reports have indicated that apical transportation of over 0.300 mm could negatively influence the sealability of the filling material (38). None of the apical values recorded after larger apical preparation exceeded this limit, except for the first coronal millimeter in Groups Reciproc and Hyflex. Although there was some transportation in the levels evaluated, the centering ability and the remaining dentin thickness found ensured the usability of the mentioned systems to perform larger apical preparation. These desirable parameters guaranteed that the slight apical transportation would not negatively influence the apical filling of the curved canals (38) and the differences in the coronal third were unlikely to be of clinical significance.

Conclusion:

The heat treated NiTi alloy systems used for larger apical preparation evenly kept the morphology of the MB and DB canals of maxillary molars. The larger apical preparation used in shaping procedures produced slight canal transportation with no evidence of significant preparation errors, however, these variations were unlikely to be of clinical significance. Working with TFA was swifter for preparing the MB canal and produced fewer changes in volume parameters. The TFA system was able to preserve the original canal anatomy with less canal transportation than Reciproc and Hyflex CM.

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Fig.1 Representative 2D reconstructions of the axial view of superimposed MB and DB roots and canals of maxillary molars before (in green) and after (in red) canal preparation, in the first and third column, respectively. Representative 3D reconstructions of side view of root canals before (green) and after (red) preparation at four levels in the coronal (C1, C2, C3 and C4), and apical thirds (A1, A2, A3, and A4) with Reciproc, Hyflex CM and TFA.

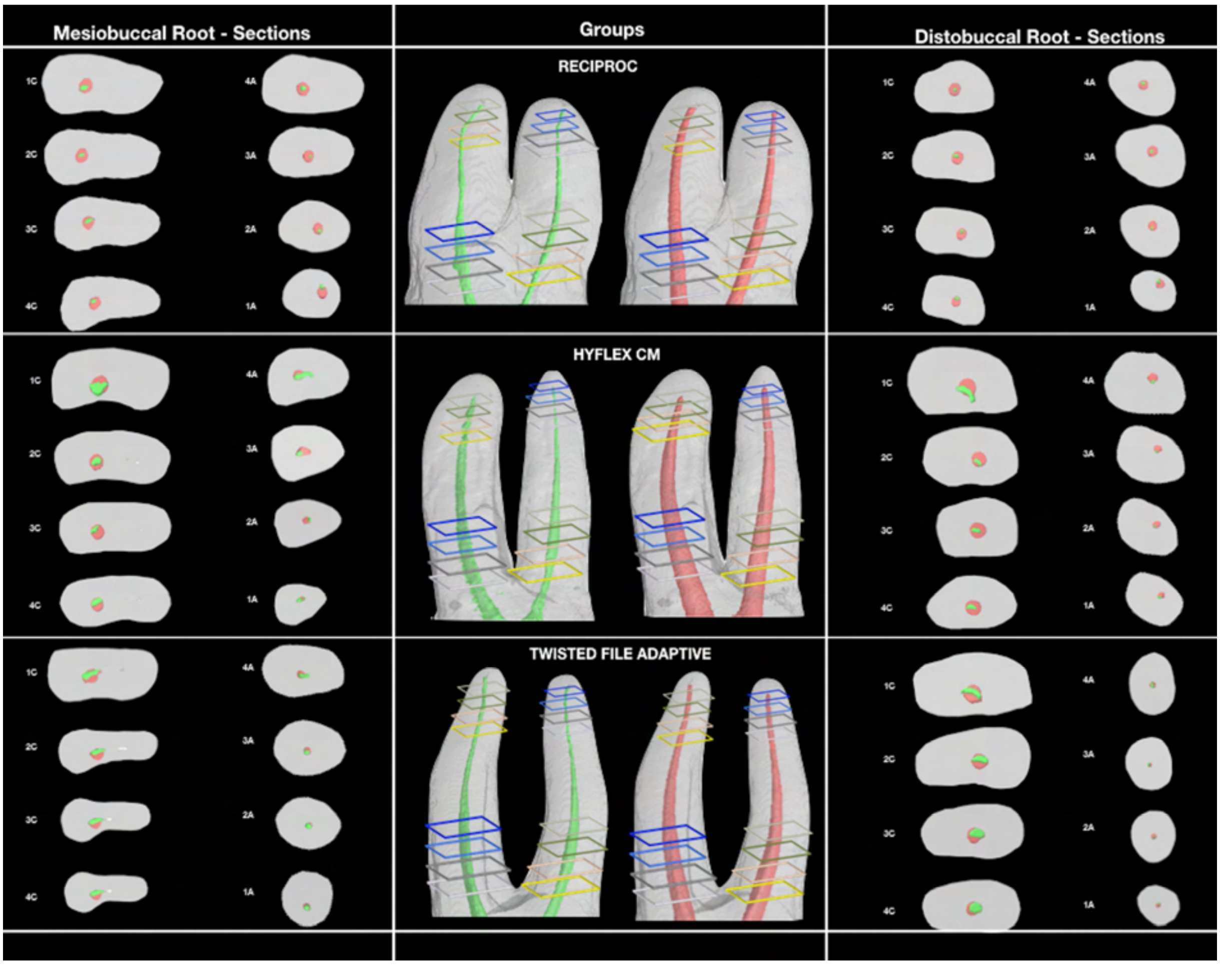

Table 1. Mean (X) and standard deviation (SD) for canal transportation. centering ability and working time in the MB and DB canals of maxillary molars evaluated after preparation with the systems tested

			Mesiobuccal (n=15)			Distobuccal (n=15)		
Systems (n)	**Thirds**	**Distance to the Apex or furcation area (mm)**	**Canal Transportation *(mm)X±SD/ Centering ability** X±SD**	**Mean Canal Transportation (mm) X±SD/ Mean Centering ability X±SD**	**Working Time (s) X±SD**	**Canal Transportation *(mm)X±SD/ Centering ability** X±SD**	**Mean Canal Transportation (mm) X±SD/ Mean Centering ability X±SD**	**Working Time (s) X±SD**
Reciproc	**Apical**	1	0.00± 0.14^{a}/ 0.47±0.30^{a}	-0.03± 0.18/ 0.49±0.30	78.20 ± 26.22^{b}	0.12± 0.20^{a}/ 0.41±0.25^{a}	0.05± 0.17/ 0.49±0.26	72.07 ± 21.94^{a}
		2	0.01± 0.17^{b}/ 0.57±0.26^{b}			0.10± 0.11^{B}/ 0.58±0.25^{b}		
		3	0.01± 0.18^{C}/ 0.51±0.34^{c}			0.06± 0.14^{c}/ 0.44±0.20^{c}		
		4	-0.12± 0.22^{D}/ 0.41±0.30^{d}			-0.09± 0.16^{d}/ 0.53±0.33^{d}		
	Coronal	4	-0.10± 0.16^{E}/ 0.40±0.24^{e}	-0.23± 0.23/ 0.37±0.30		0.04± 0.16^{e}/ 0.47±0.30^{Ee}	-0.16± 0.18/ 0.37±0.30	
		3	-0.21± 0.18^{F}/ 0.44±0.30^{f}			-0.14± 0.14^{F}/ 0.43±0.30^{f}		
		2	-0.29± 0.23^{g}/ 0.29±0.37^{g}			-0.28± 0.17^{G}/ 0.27±0.31^{g}		
		1	-0.32± 0.28^{h}/ 0.35±0.24^{h}			-0.26± 0.19^{h}/ 0.27±0.30^{h}		
Hyflex CM	**Apical**	1	0.07± 0.13^{a}/ 0.45±0.20^{a}	0.11± 0.13/ 0.45±0.25	75.60 ± 27.44^{b}	0.02± 0.09^{a}/ 0.54±0.24^{a}	0.04± 0.10/ 0.56±0.26	67.80 ± 29.71^{a}
		2	0.10± 0.17^{b}/ 0.37±0.22^{b}			0.04± 0.10^{Bb}/ 0.57±0.22^{b}		
		3	0.16± 0.11^{c}/ 0.44±0.26^{c}			0.06± 0.09^{c}/ 0.60±0.26^{c}		
		4	0.11± 0.11^{d}/ 0.56±0.30^{d}			0.04± 0.10^{Dd}/ 0.52±0.31^{d}		
	Coronal	4	0.05± 0.16^{e}/ 0.61±0.25^{e}	-0.18± 0.29/ 0.44±0.28		0.03± 0.09^{e}/ 0.65±0.24^{E}	-0.12± 0.25/ 0.40±0.30	
		3	-0.06± 0.23^{Ff}/ 0.54±0.31^{f}			-0.05± 0.21^{Ff}/ 0.39±0.31^{f}		
		2	-0.30± 0.27^{g}/ 0.34±0.20^{g}			-0.18± 0.29^{Gg}/ 0.29±0.24^{g}		
		1	-0.39± 0.24^{h}/ 0.26±0.24^{h}			-0.26± 0.27^{h}/ 0.27±0.28^{h}		
Twisted File Adaptive	**Apical**	1	0.02± 0.10^{a}/ 0.34±0.24^{a}	0.02±0.10/ 0.46±0.30	74.87 ± 26.52^{a}	-0.02± 0.08^{a}/ 0.54±0.27^{a}	0.00±0.11/ 0.51±0.28	66.50 ± 21.27^{a}
		2	-0.01± 0.10^{b}/ 0.47±0.30^{b}			0.00± 0.10^{b}/ 0.54±0.31^{b}		
		3	0.05± 0.08^{Cc}/ 0.48±0.31^{c}			0.02± 0.07^{c}/ 0.57±0.27^{c}		
		4	0.01± 0.11^{Dd}/ 0.57±0.33^{d}			0.00± 0.16^{d}/ 0.41±0.26^{d}		
	Coronal	4	-0.01± 0.11^{Ee}/ 0.48±0.38^{e}	-0.13±0.19/ 0.42±0.32		0.00± 0.11^{e}/ 0.34±0.20^{e}	-0.04±0.13/ 0.46±0.27	
		3	-0.03± 0.17^{f}/ 0.51±0.33^{f}			-0.01± 0.17^{f}/ 0.51±0.27^{f}		
		2	-0.22± 0.14^{g}/ 0.39±0.27^{g}			-0.11± 0.12^{g}/ 0.42±0.32^{g}		
		1	-0.25± 0.20^{h}/ 0.29±0.26^{h}			-0.06± 0.10^{H}/ 0.57±0.23^{H}		

* Positive values indicated transportation to the side opposite to the furcation area in MB canal and DB canal; negative values indicated transportation towards the furcation area in MB canal and DB canals. Result zero for transportation indicated that no transportation occurred.

**Centering ratio: number 1 indicated perfect centering ability. The closer the result was to zero, the worse the ability of the instrument to keep centered.

*** The same subscript letter on the same level and third indicated that there was no statistical difference (P>0.05).

Table2. Mean (X) and standard deviation (SD) for the volumes of the entire canal and apical third before and after the use of the systems analyzed

			Mesiobuccal (n=15)				Distobuccal (n=15)			
Systems	**N**	**Area analyzed***	**Initial volume (mm3) X± SD***	**Final volume (mm3) X± SD****	**Volume of dentin removed (mm3) X± SD*****	**Percentage of increase in volume (%) X± SD**	**Initial volume (mm3) X± SD***	**Final volume (mm3) X± SD****	**Volume of dentin removed (mm3) X± SD*****	**Percentage of increase in volume (%) X± SD**
Reciproc	**15**	**entire canal**	**0,89±0,28^{a}**	**2.37±0.72^{Aa}**	**1.40±0.67**	**233.81± 281.44^{a}**	**0,78±0,20^{a}**	**2.28±0.72^{A}**	**1.30±0.50^{a}**	**275.4± 255.6^{a}**
	15	**apical third**	**0,36±0,18^{b}**	**0,973±0,465^{b}**	**0.53±0.32^{a}**	**255.78± 300.44^{b}**	**0.30±0.23^{b}**	**0,98±0,79^{b}**	**0.49±0.23^{b}**	**358.43± 341.61^{b}**
Hyflex CM	**15**	**entire canal**	**0,90±0,33^{a}**	**3.21±1.30^{A}**	**1.84±0.92**	**214.51± 190.83^{a}**	**0,69±0,36^{a}**	**2.31±0.93^{Aa}**	**1.37±0.76^{a}**	**184.2± 126.16^{a}**
	15	**apical third**	**0,43±0,32^{b}**	**1,375±0,935^{b}**	**0.46±0.22^{a}**	**235.73±292.88^{Bb}**	**0.29±0.31^{b}**	**0,93±0,57^{b}**	**0.40±0.19^{b}**	**247.72± 126.16^{b}**
Twisted File Adaptive	**15**	**entire canal**	**0,48±0,16^{a}**	**2.20±1.15^{a}**	**0.69±0.42**	**73.24±76.87^{A}**	**0,37±0,18^{a}**	**1.63±1.15^{a}**	**0.44±0.28^{A}**	**65.83± 62.65^{A}**
	15	**apical third**	**0,34±0,20^{b}**	**1,51±1,06^{B}**	**0.14±0.11^{A}**	**126.45±243.29^{B}**	**0.25±0.17^{b}**	**1,18±1,12^{B}**	**0.12±0.09^{B}**	**151.05± 358.75^{B}**

* Mean volume in apical third was calculated between 1 millimeter short of the apex to 4 millimeter distant from the Apex;
**Mean volume in all thirds was calculated from the apical foramen to the coronal third (furcation area);
***Volume of dentin removed was calculated by subtracting the initial (uninstrumented) canal volume from the final (instrumented) canal volume;
**** The same subscript letter in the same region evaluated meant that there was no statistical difference (P>0.05)

Table 3: The mean (X) ± standard deviation (SD) of the anatomic root thickness, remaining dentin thickness (mm) after preparation, removal of mesial and distal dentin wall (mm) in the coronal and apical thirds in MB and DB canals of maxillary molars in the three groups.

		Mesiobuccal (n=15)			**Distobuccal (n=15)**		
Thirds	**Distance to the Apex or furcation area (mm)**	**Anatomical root thickness (mm) [X1]/ [Y1]**	**Remaining Dentin Thickness (mm) [X2]/ [Y2]**	**Removal of dentin wall (mm)** [X2-X1]/ [Y1-Y2]	**Anatomical root thickness (mm) [X1]/ [Y1]**	**Remaining Dentin Thickness (mm) [X2]/ [Y2]**	**Removal of dentin wall (mm)** [X2-X1]/ [Y1-Y2]
				RECIPROC			
Apical	**1 (Mesial)**	1.20 ± 0.36[a]	1.06 ± 0.34[a]	0.14 ± 0.11[Aa]	1.16 ± 0.43[a]	1.06 ± 0.40[a]	0.10 ± 0.06[a]
	1 (Distal)	1.34 ± 0.46[b]	1.20 ± 0.47[b]	0.14 ± 0.13[b]	1.21 ± 0.47[b]	0.43 ± 0.28[b]	0.21 ± 0.20[b]
	2 (Mesial)	1.25 ± 0.34[c]	1.07 ± 0.32[c]	0.18 ± 0.13[Cc]	1.33 ± 0.51[c]	1.20 ± 0.48[c]	0.13 ± 0.07[c]
	2 (Distal)	1.47 ± 0.49[d]	1.30 ± 0.47[d]	0.18 ± 0.11[d]	1.34 ± 0.33[d]	1.10 ± 0.28[d]	0.23 ± 0.14[d]
	3 (Mesial)	1.35 ± 0.31[e]	1.17 ± 0.34[e]	0.18 ± 0.11[Ee]	1.44 ± 0.69[e]/	1.31 ± 0.71[e]	0.14 ± 0.10[e]
	3 (Distal)	1.56 ± 0.65[f]	1.30 ± 0.63[f]	0.17 ± 0.13[f]	1.36 ± 0.28[f]	1.17 ± 0.25[f]	0.19 ± 0.08[f]
	4 (Mesial)	1.34 ± 0.32[g]	1.18 ± 0.31[g]	0.16 ± 0.10[Gg]	1.54 ± 0.90[g]	1.32 ± 0.91[g]	0.23 ± 0.12[G]
	4 (Distal)	1.48 ± 0.25[h]	1.21 ± 0.30[h]	0.27 ± 0.18[h]	1.34 ± 0.26[h]	1.20 ± 0.23[h]	0.14 ± 0.08[h]
Coronal	**4 (Mesial)**	1.35 ± 0.27[i]	1.21 ± 0.30[i]	0.14 ± 0.10[i]	1.44 ± 0.68[i]/	1.30 ± 0.72[i]	0.13 ± 0.08[i]
	4 (Distal)	1.50 ± 0.48[j]	1.30 ± 0.52[j]	0.20 ± 0.11[j]	1.34 ± 0.27[j]	1.16 ± 0.24[j]	0.18 ± 0.10[j]
	3 (Mesial)	1.37 ± 0.25[k]	1.21 ± 0.33[k]	0.17 ± 0.10[k]	1.62 ± 0.88[k]/	1.35 ± 0.93[Kk]	0.27 ± 0.09[K]
	3 (Distal)	1.59 ± 0.62[l]	1.24 ± 0.66[l]	0.35 ± 0.14[Ll]	1.32 ± 0.16[l]	1.20 ± 0.18[l]	0.12 ± 0.10[l]
	2 (Mesial)	1.42 ± 0.22[m]	1.28 ± 0.26[m]	0.13 ± 0.17[m]	1.49 ± 0.41[m]/	1.12 ± 0.42[m]	0.37 ± 0.13[m]
	2 (Distal)	1.43 ± 0.25[n]	1.05 ± 0.27[n]	0.38 ± 0.17[n]	1.37 ± 0.15[n]	1.28 ± 0.16[n]	0.09 ± 0.09[n]
	1 (Mesial)	1.53 ± 0.16[o]	1.35 ± 0.19[o]	0.19 ± 0.17[o]	1.61 ± 0.40[o]	1.23 ± 0.43[Oo]	0.38 ± 0.14[o]
	1 (Distal)	1.57 ± 0.34[p]	1.12 ± 0.31[p]	0.44 ± 0.24[p]	1.50 ± 0.15[p]	1.38 ± 0.16[p]	0.12 ± 0.11[p]
				HYFLEX CM			
Apical	**1 (Mesial)**	1.12 ± 0.29[a]	0.92 ± 0.28[a]	0.20 ± 0.10[a]	0.99 ± 0.28[a]	0.90 ± 0.29[a]	0.09 ± 0.08[a]
	1 (Distal)	1.05 ± 0.25[b]	0.92 ± 0.23[b]	0.13 ± 0.08[b]	1.05 ± 0.34[b]	0.92 ± 0.30[b]	0.13 ± 0.08[b]
	2 (Mesial)	1.21 ± 0.25[c]	0.99 ± 0.26[c]	0.21 ± 0.13[c]	1.16 ± 0.27[c]	1.06 ± 0.28[c]	0.10 ± 0.07[c]
	2 (Distal)	1.23 ± 0.26[d]	1.12 ± 0.24[d]	0.11 ± 0.08[d]	1.16 ± 0.32[d]	1.01 ± 0.31[d]	0.16 ± 0.09[d]
	3 (Mesial)	1.28 ± 0.21[e]	1.01 ± 0.22[e]	0.27 ± 0.11[e]	1.30 ± 0.22[e]	1.17 ± 0.24[e]	0.13 ± 0.07[e]
	3 (Distal)	1.34 ± 0.21[f]	1.23 ± 0.19[f]	0.11 ± 0.07[f]	1.29 ± 0.30[f]	1.10 ± 0.29[f]	0.19 ± 0.09[f]
	4 (Mesial)	1.34 ± 0.23[g]	1.09 ± 0.25[g]	0.26 ± 0.08[g]	1.30 ± 0.24[g]	1.16 ± 0.27[g]	0.13 ± 0.10[Gg]
	4 (Distal)	1.33 ± 0.21[h]	1.18 ± 0.20[h]	0.15 ± 0.08[Hh]	1.31 ± 0.28[h]	1.13 ± 0.28[h]	0.18 ± 0.11[h]
Coronal	**4 (Mesial)**	1.34 ± 0.25[i]	1.09 ± 0.26[i]	0.25 ± 0.07[I]	1.31 ± 0.27[i]	1.14 ± 0.31[i]	0.17 ± 0.08[i]
	4 (Distal)	1.36 ± 0.19[j]	1.14 ± 0.23[j]	0.22 ± 0.13[j]	1.34 ± 0.25[j]	1.15 ± 0.28[j]	0.19 ± 0.11[j]
	3 (Mesial)	1.42 ± 0.24[k]	1.18 ± 0.27[k]	0.23 ± 0.14[k]	1.33 ± 0.21[k]	1.09 ± 0.29[K]	0.24 ± 0.21[Kk]
	3 (Distal)	1.36 ± 0.20[l]	1.10 ± 0.29[l]	0.26 ± 0.16[L]	1.33 ± 0.26[l]	1.15 ± 0.25[l]	0.19 ± 0.13
	2 (Mesial)	1.44 ± 0.18[m]	1.26 ± 0.29[m]	0.18 ± 0.17[m]	1.37 ± 0.17[m]	1.05 ± 0.30[Mm]	0.32 ± 0.23[m]
	2 (Distal)	1.42 ± 0.17[n]	1.01 ± 0.31[n]	0.41 ± 0.22[n]	1.40 ± 0.23[n]	1.25 ± 0.23[n]	0.15 ± 0.13[n]
	1 (Mesial)	1.55 ± 0.10[o]	1.38 ± 0.28[o]	0.17 ± 0.22[o]	1.53 ± 0.22[o]	1.15 ± 0.29[O]	0.38 ± 0.25[o]
	1 (Distal)	1.48 ± 0.20[p]	1.02 ± 0.29[p]	0.46 ± 0.18[p]	1.55 ± 0.24[p]	1.42 ± 0.26[p]	0.14 ± 0.14[p]
				TWISTED FILE ADAPTIVE			
Apical	**1 (Mesial)**	1.22 ± 0.41[a]	1.12 ± 0.38[a]	0.10 ± 0.08[a]	1.14 ± 0.38[a]	1.03 ± 0.37[a]	0.11 ± 0.07[a]
	1 (Distal)	1.07 ± 0.43[b]	0.99 ± 0.42[b]	0.08 ± 0.06[b]	1.03 ± 0.23[b]	0.94 ± 0.22[b]	0.09 ± 0.05[b]
	2 (Mesial)	1.28 ± 0.34[c]	1.18 ± 0.35[c]	0.10 ± 0.09[c]	1.27 ± 0.38[c]	1.17 ± 0.39[c]	0.10 ± 0.07[c]
	2 (Distal)	1.34 ± 0.38[d]	1.22 ± 0.39[d]	0.12 ± 0.06[d]	1.18 ± 0.24[d]	1.08 ± 0.24[d]	0.10 ± 0.06[D]
	3 (Mesial)	1.40 ± 0.33[e]	1.27 ± 0.34[e]	0.14 ± 0.05[e]	1.35 ± 0.38[e]	1.25 ± 0.39[e]	0.09 ± 0.06[e]
	3 (Distal)	1.36 ± 0.37[f]	1.28 ± 0.38[f]	0.09 ± 0.06[f]	1.29 ± 0.25[f]	1.18 ± 0.24[f]	0.11 ± 0.07[F]
	4 (Mesial)	1.49 ± 0.31[g]	1.35 ± 0.28[g]	0.14 ± 0.08[g]	1.44 ± 0.49[g]	1.32 ± 0.43[g]	0.12 ± 0.14[g]
	4 (Distal)	1.39 ± 0.45[h]	1.25 ± 0.46[h]	0.13 ± 0.06[h]	1.33 ± 0.24[h]	1.21 ± 0.23[h]	0.12 ± 0.05[h]
Coronal	**4 (Mesial)**	1.44 ± 0.31[i]	1.31 ± 0.30[i]	0.12 ± 0.05[i]	1.42 ± 0.31[i]	1.31 ± 0.30[i]	0.12 ± 0.04[i]
	4 (Distal)	1.35 ± 0.41[j]	1.22 ± 0.44[j]	0.13 ± 0.11[j]	1.36 ± 0.41[j]	1.22 ± 0.44[j]	0.13 ± 0.11[j]
	3 (Mesial)	1.48 ± 0.26[k]	1.33 ± 0.28[k]	0.15 ± 0.07[k]	1.47 ± 0.26[k]	1.32 ± 0.28[k]	0.14 ± 0.07k
	3 (Distal)	1.37 ± 0.48[l]	1.18 ± 0.50[l]	0.18 ± 0.15[l]	1.37 ± 0.48[l]	1.18 ± 0.50[l]	0.19 ± 0.14
	2 (Mesial)	1.46 ± 0.24[m]	1.34 ± 0.27[m]	0.11 ± 0.06[m]	1.45 ± 0.24[m]	1.32 ± 0.28[M]	0.13± 0.10[M]
	2 (Distal)	1.43 ± 0.42[n]	1.09 ± 0.45[n]	0.34 ± 0.14[n]	1.44 ± 0.42[n]	1.12 ± 0.46[n]	0.32± 0.14[N]
	1 (Mesial)	1.54 ± 0.20[o]	1.45 ± 0.19[o]	0.09 ± 0.08[o]	1.56 ± 0.21[o]	1.43 ± 0.20[o]	0.13 ± 0.18[O]
	1 (distal)	1.55 ± 0.42[p]	1.21 ± 0.47[p]	0.34 ± 0.18[p]	1.53 ± 0.41[p]	1.24 ± 0.47[p]	0.30 ± 0.16[P]

X1: measurement of the thickness of mesial wall in MB root or distal wall in DB root before shaping procedure.
X2: measurement of the thickness of mesial wall in MB root or distal wall in DB root after shaping procedure.
Y1: measurement of the thickness of distal wall in MB root or mesial wall in DB root before shaping procedure.
Y2: measurement of the thickness of distal wall in MB root or mesial wall in DB root after shaping procedure.
**** The same subscript letter in the same region evaluated meant that there was no statistical difference (P>0.05).

3 Discussion

3 DISCUSSION

The importance of respecting the original canal anatomy and avoiding transportation is that better preservation of the original canal shape resulted in increased success rates (Pettiette; Delano ; Trope M, 2001). Whereas, the presence of ledge in root canals led to lower success rates (CHEUNG; LIU, 2009). According to Bürklein S, Schäfer E (2013a), canal transportation could vary from slight change in the axis of the canal, denominated Type 1, with minimal movement of the apical foramen, to Type III, severe change in relocation of the apical foramen. This latter classification usually requires a corrective apical surgery after filling the canal in the best possible manner, while in the case of Type I, after cleaning the canal conventional filling can be performed. The intermediate classification (Type II) of canal transportation requires placement of a biocompatible barrier (e.g., MTA) before filling to prevent the extrusion of filling material from the root canal system into the periapical tissues.

Before the era of the NiTi instruments, the main root canal instrumentation concept was based on minimally invasive procedures to avoid transportation and perforations resulting from aggressive apical instrumentation (WU et al.,2000). In addition, at that time, the best success rate was associated with the small apical diameter preparation (STRINDBERG, 1956; KEREKES; TRONSTAD, 1979). The development of the NiTi alloys resulted in a more flexible and resistant materials for the instrumentation of curved canals (SHEN et al.,2013a). Recently, a clinical study showed a new possibility for negotiating and preparing the MB2 canals efficiently using a single file made of M-wire, compared with a #10 K file (ZUOLO; CARVALHO; DE-DEUS, 2015), but no information was available about the canal transportation in the MB2 canal. Furthermore, with the introduction of the heat treated NiTi files, featuring more flexible and resistant files (SHEN et al. 2013), the evaluation of apical transportation in canals with larger apical preparation was still lacking. This evaluation would be important because the larger preparations have potential to straighten the canal (THOMPSON et al.2014) and might cause undesirable weakening of the tooth structure, whereas smaller preparations may leave tissue remnants and infected dentin behind (SCHÄFER; DAMMASCHKE, 2006).

The main benefits of the larger apical preparation would be the potential contribution to access of the antimicrobial irrigant (2.5% NaoCL) providing the best activity of the irrigant (RODRIGUES et al., 2017). This was explained because the enlargement of the canal resulted in a larger volume of irrigant used, which remained in the canal longer and had a larger volume of irrigant in the canals used, and increased the chances for improved chemical effects(RODRIGUES et al., 2017). In addition, the enlargement of the master apical size had the potential to reduce the microbial flora in the root canal (ØRSTAVIK; KEREKES; MOLVEN, 1991; DALTON et al., 1998; SHUPING et al.,2000; MCGURKIN-SMITH et al., 2005). Furthermore, a clinical study recommended that for patients with necrotic pulps and periapical lesions, larger apical preparation size would result in an increased healing outcome relative to the radiographic and clinical evaluations (AMINOSHARIAE; KULILD, 2015).

In this study, all canal configuration parameters were evaluated using micro-CT technology. Micro-computed tomography has been favored over other methodologies, such as cone beam (YANG et al., 2011; GUIMARÃES et al., 2017; PETERS; BOESSLER;PAQUÉ, 2010; MARCELIANO-ALVES et al., 2015; SANT'ANNA et al.,2014; SHENOI et al.,2017), radiographic evaluations (BÜRKLEIN; BÖRJES; SCHÄFER, 2014; SABER; NAGY; SCHÄFER, 2015) and using digital imaging cameras (THOMPSON et al., 2014), for non-invasive and reproducible three-dimensional evaluation of root canal systems (ZHAO et al.,2013; MARCELIANO-ALVES et al., 2015).

The canal transportation evaluated in the coronal and apical thirds of MB2 canals of maxillary first molars and MB/DB canals of maxillary molars was performed according to Gambill (1996) . In all canals evaluated in this investigation the coronal transportation moved toward the furcation area, whereas in the apical third, the transportation occurred in the opposite direction. All systems evaluated in MB2 canals showed similar performance relative to apical and coronal transportation and had similar centering ability. The results for the MB2 canal showed severe canal transportation in the coronal third for all systems and indicated that thinner remaining dentin thickness resulted from instrumentation with larger tapered files, even when they were made of more flexible alloys. The lack of studies assessing the parameters (canal transportation, canal volume, shaping time, remaining dentin thickness) evaluated in MB2 canal made it difficult to compare our results with those of previous findings in the literature.

The mean values of the first millimeter of apical transportation and the centering ability in the apical third in MB and DB canal of maxillary molars were not statistically different. As from 2 millimeters, the mean apical transportation and the mean coronal transportation values in the two canals showed some differences in the levels evaluated. These findings could be attributed to the distinct taper of the files (4% for TFA vs. 6% for HF and 6% REC). The more an instrument is tapered, the faster the core diameter increases, resulting in reduced flexibility of the file (BÜRKLEIN; SCHÄFER, 2013b). This may explain the reason for less transportation and lower volume change values caused with TFA. The lower canal transportation values observed in TFA(35/.04) could be associated with the reduced cross-sectional area and high flexibility of the R-phase instrument. Some studies with smaller sized apical preparation using TFA observed less canal transportation (GERGI et al, 2015; GERGI et al, 2014) or similar canal transportation (CAPAR et al., 2014a; ORDINOLA-ZAPATA et al., 2014). Although significant discrepancies concerning canal transportation were observed, the clinical relevance of the means obtained in the apical third of MB and DB canals respectively by Reciproc X (-0.3mm/0.05 mm), Hyflex CM (0.11mm/0.04mm) and TFA (0.02mm/0.00mm) instruments continues to be questionable (HÜLSMANN; PETERS; DUMMER, 2005, SABER; NAGY; SCHÄFER, 2015) and are probably of limited importance in these moderately curved canals. No obvious procedural mistakes were identified in the MB and DB canal study, reinforcing findings reported in previous studies, conducted under similar experimental conditions, using micro-computed tomography for evaluating the preparation of canals with Hyflex CM and TFA with (30/04) (ZHAO et al., 2013) and 25/08 (MARCELIANO-ALVES et al., 2015) apical sizes preparation. In both studies (ZHAO et al., 2013; MARCELIANO-ALVES et al., 2015), TFA and Hyflex CM showed the less canal transportation compared with the other systems. In our study, this point was observed only in the first apical millimeter, indicating the potential of the flexible alloy in the smaller core of the material (SHEN et al., 2013a; HÜLSMANN; PETERS; DUMMER, 2005). However, canal transportation was significantly manifested in the present experiment with the significant differences starting at 2 mm of apical third. Similar to our results, Hyflex CM with lower apical sizes prepared the canals and maintained the canal anatomy without significant errors ((ZHAO et al., 2013; MARCELIANO-ALVES et al., 2015). Furthermore, the mean value of canal transportation of Hyflex at 4 mm from the foramen revealed the highest mean apical transportation value for Reciproc and Hyflex. Thompson et al. (2014) reported that in the resin block, the simulated canals with 45º curvature resulted in the tendency of straightening at the beginning of the curvature, resulting in more removal of the acrylic. Similarly, the higher apical transportation at 4mm from the apical foramen was observed in more tapered files tested (Hyflex CM and Reciproc). Reciproc at this level had the tendency towards deviation to distal side, probably because of the lower flexibility compared with the other files tested. The composition of NiTi alloy in TF (R phase) and Hyflex CM (CM-wire) makes the instruments more ductile, reducing the intensity of the forces (SABER; NAGY; SCHÄFER, 2015b; PONGIONE et al., 2012). The great shaping ability can be attributed to the enhanced flexibility of these instruments. Hyflex CM files have been reported to have significantly less bending stiffness, better flexibility and cyclic fatigue resistance than M-wire and traditional nickel-titanium instruments (GOO et al., 2017). Although the alloy of Hyflex CM was shown to have high flexibility during instrumentation, the spirals of Hyflex CM have been reported to be distorted (unwound) in at least 80% (CAPAR et al., 2014b) or 95% (NEVARES et al., 2015) of the instruments. The unwound Hyflex CM with large tip/taper (40/.06) rotating within the canal may explain the difference in canal transportation among other groups. Clinically, the knowledge of file behavior is a relevant factor to be considered in the selection of the instrument used to prepare flattened canals or those with a high degree of curvature, because they would have more straightening tendency at the beginning of curvature (VERTUCCI, 2005; SHEN et al., 2013a; HÜLSMANN; PETERS; DUMMER, 2005).

Distinct kinematics developed in the NiTi systems have been proposed to maintain the original canal shape and thus keep it better centered (SCHÄFER; LOHMANN, 2002). Furthermore, the current literature has reported the potential of reciprocating motion to exhibit excellent resistance to cyclic fatigue with a tendency towards lower canal transportation than the instruments with continuous rotating motion (AHN; KIM; KIM, 2016; PLOTINO et al., 2015). The influence of kinematics on the NiTi systems tested in Articles 1 and 2 seemed to have no influence on canal transportation, as shown in other studies (CAPAR et al., 2013; BÜRKLEIN; BENTEN S; SCHÄFER, 2013c; YOU et al., 2011). In the literature, there are conflicting results about the effects of reciprocating instruments versus rotary movement on root canal transportation in ex vivo studies (GERGI et al., 2014; GERGI et al., 2015; ZHAO et al., 2013; MARCELIANO-ALVES et al., 2015; CAPAR et al., 2014a; SABER; NAGY; SCHÄFER, 2015a), while in the in vitro studies using simulated canals prepared with rotary motion, this promoted more canal transportation (SALEH et al., 2015; GIULIANI et al., 2014; BERUTTI et al., 2012). The difference in ex vivo studies may lie in the fact that the more complex root canal system in extracted teeth has more irregularities compared with the simulated canal in resin blocks (AHN; KIM; KIM, 2016). Moreover, the current reciprocating techniques usually require only one file, whilst the rotary systems used require a gradual sequence of files to shape the canal. This may have been responsible for the better centering ability in ex vivo study using the continuous rotary motion compared with the reciprocating motion (GIULIANI et al., 2014). Concerning the influence of the kinematics on the change in volume, it could be speculated that the movement could interfere in the cutting efficiency of the systems assessed. Some studies (STERN et al., 2012; GAMBARINI, 2014) have stated that both (rotary and reciprocating motion) did not influence the cutting efficacy of the file, and removed similar volumes of dentin. Previous studies have shown that the different movements (reciprocating and continuous rotation) in TFA and Reciproc used in their proprietary kinematics did not reduce the cutting ability of these files (GAMBARINI, 2014; GAMBARINI et al., 2016), and that the cutting ability was not reduced by prolonged use in 10 plastic blocks (GAMBARINI et al., 2016). An extra point to be considered is the influence of the kinematics used to prepare the canal on apical debris extrusion - an undesirable event in root canal therapy - because extrusion of the canal content such as dentin, necrotic pulp tissue, and bacteria (KUŞTARCI; AKPINAR; ER, 2008) reacts with inflammation of the periapical tissue (SIQUEIRA, 2003). There is no consensus in contemporary literature about the ability of rotary, or reciprocating movements to extrude more apical debris extrusion (AHN; KIM; KIM, 2016; PLOTINO et al., 2015). Some interesting points to be considered when comparing the two movements is the potential of the non cutting directions (clockwise) of the reciprocating movement to be responsible for the apical debris extrusion, and the reduced number of files in the reciprocating technique to be capable of reducing it (YOU et al., 2010; DE-DEUS et al., 2010b). On the other hand, when more debris was found with reciprocating techniques, the rotary motion was pointed out as causing increase in the coronal transportation of dentin chips and debris by acting like a screw carrier (BÜRKLEIN; SCHÄFER, 2012). In these contexts, it seems prudent to point out that in our studies the type of alloy and the instrument design exerted greater influence on canal transportation rather than the type of motion itself.

Change in volume, an important parameter to evaluate, is directly influenced by the cutting efficiency of the file to remove dentin. This cutting efficacy of instruments involves a complex interrelationship of several factors such as cross-sectional design, debris removal capacity, helical and rake angles, metallurgical properties and surface treatments (PLOTINO et al., 2014; SCHÄFER; LAU, 1999; SCHÄFER; OITZINGER, 2008; PETERS et al., 2014). The cutting efficacy of reciprocating single-file systems has previously been evaluated, and the Reciproc system was shown to be more effective than WaveOne (PLOTINO et al., 2014) and other rotary instruments (CAPAR et al., 2014a). As mentioned above, these differences may be caused by the different cross-sectional designs rather than by different kinematics. The greater cutting efficacy of the Reciproc instrument is probably related to its S-shaped cross-section with a double-cutting edge. This may explain the better ability of MTwo (which is morphologically similar to Reciproc) to produce a higher value of change in the entire MB2 canal compared with Prodesign R(CM-Wire). In addition, heat-treated alloys have been shown to have less stiffness (GAMBARINI et al., 2011) and a lower ultimate tensile strength those of conventional superelastic wires (ZHOU et al., 2012), suggesting that heat-treated alloys are softer and therefore cut less effectively. In the MB and DB canal preparation (Article 2), the similarity between the apical change in volume in Reciproc (40/.06) and Hyflex CM (40/.06) may be related to the dimensional similarity of the cross-section of the more tapered files compared with TFA (35/.04). The results found with Reciproc corroborated those of Gergi et al. (2015) and Capar et al. (2014a) who reported that Reciproc produced a higher change in volume values compared with the TFA. Dissimilarities in the cross-sectional design between the instruments may explain this difference.

Essentially, the purpose of evaluating the working time of any instrument or technique is to express conclusions about the efficacy of the device or method and its clinical suitability. Overall, in both articles of this thesis, all files tested showed a short clinical time spent to prepare the canals, irrespective of the filing technique. The mean time of all systems tested in Article 1 (170.5 sec.) and Article 2 (CMB – 76,22 sec., and CDB - 68,70 sec.) indicated interference of the anatomical features of the canals in the ability of the file to cut and prepare them. It is noteworthy that in Article 1, the Reciproc, Prodesign R and Mtwo systems used one, two and four instruments respectively. The role the canal anatomy played in shaping time was so important that even the Reciproc system that used only one file, presented a higher mean working time value than those of all the groups tested in Article 2, irrespective of the canals (MB or DB) evaluated. The great difference in methodology and individual aspects related to the operator made it most difficult to compare many results in the literature concerning instruments or the techniques when using the working time records. Some experiments evaluated the total time to shape the root canal, clean the flutes, change the files, and irrigate (SABER; NAGY; SCHÄFER, 2015a; SALEH et al., 2014; BÜRKLEIN et al., 2012a; BÜRKLEIN; BENTEN; SCHÄFER, 2014a). Whereas, in Article 1 and 2 of this thesis, the time recorded was restricted to the time in which the file worked on the canal wall. Thus, data from different studies should be compared with caution, because of the variation caused by individuals (LEV et al., 1987) or by methodologies. Those variations cannot be controlled precisely, but should be recognized as decisive in many cases. Additionally, it seems to be more appropriate to use the working time as a parameter for the evaluating the efficacy of an instrument than the measurement of its cutting ability (SCHÄFER; TEPEL; HOPPE, 1995; TEPEL; SCHÄFER; HOPPE, 1995). Evaluation of the shaping time (ST) offers knowledge about the capability of the system to diminish this ST, thus allowing the clinicians to spend more time refreshing the irrigant (NaOCl) with activation techniques that have enhanced the cleaning and disinfection of the root canal (GU et al., 2009).

The new generation of endodontic files, represented by the heat treated NiTi files, is remarkable because of the optimized microstructure of the NiTi wire blanks. Thermomechanical processing is a complicated method that combines hardening and heat treatment into a single process (ALAPATI et al., 2009a). The heat treatment formula is proprietary knowledge, and this process can adjust an appropriate heat treatment. Although more details about this process remain unknown, the enhancement of mechanical properties has opened a new perspective for contemporary endodontic instruments to clean and shape the complicated curved canals even more efficiently and safely (SHEN et al., 2013b). The heat treatment technology in the NiTi alloy manufacturing process has considerably altered the superelasticity and shape memory properties of NiTi alloys (KUHN; TAVERNIER; JORDAN, 2001; Kuhn; Jordan, 2002; CONDORELLI et al., 2010; YONEYAMA et al., 1993; THOMPSON, 2000). Moreover, little variations in composition, impurities, and thermomechanical processing have an influence on the mechanical properties of NiTi alloys (CONDORELLI et al., 2010), that have the potential to improve the clinical performance of the instruments. In this study, four types of NiTi files were used to shape the canals: conventional alloy(Mtwo), M-Wire alloy(Reciproc), CM-Wire alloy (ProdesignR and Hyflex CM) and R-phase alloy. A hybrid microstructure is featured in the Metallurgical Characterization of the alloy of which Controlled Memory and M-Wire NiTi Instruments are made, and in the clinical use of the files (MCKELVEY; RITCHI, 2001) this resulted in the rise in austenite transformation temperatures, at body temperature (37ºC). By means of differential scanning calorimetric investigations it was observed that standard superelastic NiTi wire had the austenite arrangement, whereas M-Wire was a blend of an amount of R-phase, austenite (ALAPATI et al., 2009) and martensite microstructures (YE; GAO, 2012; PETERS; DE AZEVEDO; PEREIRA, 2017). CM-Wire in turn, was a hybrid of martensite and austenite structure (SHEN et al., 2011b; PETERS; DE AZEVEDO; PEREIRA, 2017) and R-phase contents in the microstructure in the austenite phase (SHEN et al., 2012). The main advantage of the martensitic structure in a heat treated NiTi file is to favor the performance of this aforementioned file for many purposes (SHEN et al., 2013b). The amount of martensite in the alloy during the shaping procedure is dependent on the final austenite transformation temperature. The temperature at which this event occurs is the austenite finish temperature (Af), which indicates that at Af and above this referenced limit, the material will have completed its shape memory transformation and will present its superelastic properties (SHEN et al., 2013a). The austenite final transformation temperature of conventional NiTi wire, twisted file, M-Wire, and CM-Wire are relatively 16ºC-31ºC, 17ºC, 50ºC, and 55ºC, respectively (SHEN et al., 2011b; ZHOU et al., 2012; YE; GAO, 2012; HOU et al., 2011). The amount of martensite and austenite microstructure are distinct in CM-Wire and Conventional-Wire systems (SHEN et al., 2013b). For root canal treatment, especially in curved canals, the presence of a martensite composition displays an exceptional fatigue resistance and faster ability to deform the instrument (SHEN et al., 2013a). In terms of transportation in shaping procedures, the presence of martensite is desirable in clinical use, because it provides more the file with more flexibility and it helps to keep the long axis of the canal more centered (SCHÄFER; DAMMASCHKE, 2006; ZHOU et al., 2013; Bürklein; Schäfer, 2013b). The effect of the microstructure of these new heat treated instruments could explain the absence of difference in centering ability in the apical third in the canals evaluated (MB2, MB and DB canals) and the slight apical transportation caused by the use of larger tip and taper instruments. On the other hand, the more flexibility of the CM-wire alloy probably interfered negatively in the ability of the CM-Wire to negotiate the MB2 canal. This shortcoming probably occurred because of the amount of martensite composition in CM-Wire alloys, resulting in the superior flexibility of this file, when compared with those that contain more austenite composition (SHEN et al., 2013b), thus increasing the difficulty of the initial cutting action of the flutes. This limitation of CM Wire instruments has previously been hypothesized (ALCALDE et al., 2017). This fact may explain the reduced percentage of ProdesignR (40%), compared with MTWO (60%) and Reciproc (60%) to achieve patency in the MB2 canals. In terms of failure prevention, presence of the martensite microstructure provided more resistance to fatigue crack propagation in treated Niti files, because this microstructure was more resistant to fatigue-crack growth than stable austenite, as was found by analyzing the fatigue performance of the different microstructures in the NiTi alloys (PETERS; DE AZEVEDO; PEREIRA, 2017). The resistance to fatigue failure has been previously reported indicating that M-wire wire was up to 400% resistant than conventional NiTi wire (JOHNSON et al., 2008) and the resistance of CM-Wire ranges from 300% to

800% higher than that of conventional NiTi instruments (SHEN et al., 2011a). Compared with M-wire NiTi instruments, the CM-Wire technology provided more resistance to cyclic fatigue, whilst M-Wire instruments had more torsional resistance to failure showing higher deformation before failure (PETERS; DE AZEVEDO; PEREIRA, 2017; ALCALDE et al., 2017). These distinct behaviors are inherent to their microstructural composition and explain the absence of the file separation when the Reciproc (M-wire) was used to prepare the narrow MB2 canals. In addition, the file separation of Mtwo and Prodesign R instruments may primarily be associated with torsional failure, because of the narrower MB2 canal configuration (VERTUCCI, 2005; DEGERNESS; BOWLES, 2010).

The reduction in the remaining dentin thickness was an additional and critical point found in the evaluation of root canal instrumentation, because excessive enlargement of the root canal space can lead to misfortunes such as stripping or perforations (HÜLSMANN; PETERS; DUMMER, 2005; Bürklein; Schäfer, 2013b). For MB2 canal preparation, one case of perforation was identified in each Group Mtwo and Group Reciproc. At least 37.5% (5/8) of Prodesign R samples showed a remaining dentin thickness of less than 0.5 millimeters in the danger zone. The Reciproc and Mtwo systems showed 55.5% (5/9) and 66.6% (6/9), respectively. Elayouti et al. (2008) indicated 0.5 millimeters as the minimum measurement established for evaluating canals with narrowness similar to that exhibited in the MB2 canal.

Since Yared (2008) introduced the approach to shaping a curved canal using the single file concept, Tapered files with a reduced numbers of instruments have been widely used and accepted for cleaning and shaping the canal space. The instrumentation technique, irrespective of using single or hybrid files, those with a smaller taper may diminish the risk of procedural mishaps and improper accidents during cleaning and shaping procedures, but they may jeopardize the process of cleaning the canal system and placing the filling material (RUNDQUIST; VERSLUIS, 2006). On the other hand, the technique with too large a taper may improve the cleaning procedure (particularly in the coronal and mid-root thirds), but may also enhance the potential for strip perforations (RUNDQUIST; VERSLUIS, 2006), as seen in the MB2 canal preparation with Reciproc and Mtwo systems. In addition, other procedural accidents may happen and predispose the root to vertical fracture, if greater reduction of the root structure does indeed increase stress on the canal wall (RUNDQUIST; VERSLUIS, 2006). For MB2 canals, in addition to the perforation found with the use of MTWO (25./06) and Reciproc (25/.08) in the "danger zone", thinner areas were detected. Furthermore, the highest efficient flutes on Reciproc and Mtwo has been previously documented (SCHÄFER;

ERLER; DAMMASCHKE, 2006; PLOTINO et al., 2014), and was associated with the larger taper causing perforation and stripping on the distal wall in the danger zone of the complex MB2 canal. This accident in shaping procedure surely displayed the role of root canal anatomy and confirmed that higher coronal transportation values compared with those of apical transportation were found for both studies. This was explained because the tapered file produced a bigger core diameter and it further increased stiffness of the file, irrespective of the type of alloy (Bürklein; Schäfer, 2013b). Probably, the development of new files with different designs, including reduced tapers in their designs would be necessary to prevent accidents and the reduced remaining dentin thickness in the narrowest canals, such as the MB2 canals. The difference in anatomical configuration of MB2 and MB1/DB canals and the taper effect on the cited alloy systems, absolutely explained the different pattern of remaining dentin thickness in the results shown in Articles 1 and 2. In Article 2, even when larger taper and tips (35/.04 and 40/.06) were used to prepare MB and DB canals with the three systems (Twisted file adaptive, Hyflex CM and Reciproc), all systems kept the remaining dentin thickness higher than 0.3 mm (LIM; STOCK, 1987). Similarly to our findings, Santana et al. (2014) found that the larger apical preparation (#25 and #40) using Mtwo and Reciproc systems significantly increased the root canal volume in the apical third without significantly diminishing the dentin thickness in the danger zone for the two instrument systems.

In the MB2 canal, there were no statistically significant differences in apical transportation with the systems evaluated. Although statistically significant difference in apical transportation were observed for the MB and DB canals in some levels, from a clinical point of view, these differences were of limited importance (Fig. 1). Taking into account that curved canals were prepared, the clinical relevance of a maximum difference of mere mean value of 0.160 mm in the apical canal transportation caused by the different instruments remains questionable. For the MB2 canal and MB/DB canals, all measurements in the apical thirds were not above the limit of 0.300 mm indicated by LIM, as a safe remaining dentin thickness. In addition, lower values of 300µm for apical transportation are desirable and have been stipulated as a maximum value that could interfere negatively in the sealing ability (WU; FAN; WESSELINK, 2000a). Thus, it could be concluded that all three instruments tested maintained the original canal curvature well in the apical third. In the coronal third, the over-enlargement of this area, causing stripping or perforation were detected only when tapered files were used to prepare the more complex anatomy existent in danger zone of the MB2 canals.

4 CONCLUSION

4 CONCLUSION

- The three mechanized systems demonstrated similar performance when negotiating and shaping the MB2 canal. However, the Reciproc file reached the full working length faster than Prodesign R file. Mtwo and Reciproc files removed more dentin in the inner furcation area when compared with PDR. In addition, files with a .06 and .08 taper removed excessive amount of dentin in the inner furcation area and were more prone to causing a strip-perforation in the coronal third.

- The heat treated NiTi alloy systems used for larger apical preparation evenly maintained the morphology of MB and DB canals of maxillary molars. The larger apical preparation effect on shaping procedures produced slight canal transportation with no evidence of significant preparation errors, however, these variations may not be clinically significant. Use of TFA was swifter to prepare the MB canal and produced fewer changes in volume parameters. With the TFA system it was possible to preserve the original canal anatomy with less canal transportation than produced by the Reciproc and Hyflex CM systems.

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APPENDIXES

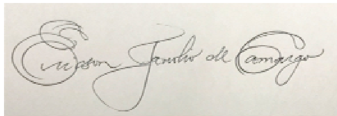
APPENDIX A

DECLARATION OF EXCLUSIVE USE OF THE ARTICLE IN DISSERTATION/THESIS

We hereby declare that we are aware of the article, **The influence of new heat–treated NiTi alloy on shaping ability and apical transportation of maxillary molars. The evaluation of the larger apical preparation on mesiobuccal and distobuccal canals of maxillary molars: A micro-computed study**, will be included in Thesis of the student, Ericson Janolio de Camargo, was not used and may not be used in other works of Graduate Programs at the Bauru School of Dentistry, University of São Paulo.

Nov 10, 2017

Ericson Janolio de Camargo
Author



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Rodrigo Ricci Vivan
Author

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APPENDIX B

Table 1 – The absolute values for the transportation (mm) and the centering ability of the MB2 canal for the systems evaluated.

	Reciproc (25/08)				Reciproc (25/08)			
Sample	**Apical Transportation**				**Coronal Transportation**			
	1	2	3	4	4	3	2	1
Specimen 1	0,013	0,099	0,079	-0,104	-0,664	-0,761	-0,549	-0,073
Specimen2	-0,093	-0,198	0,201	0,236	-0,215	-0,470	-0,657	-0,816
Specimen 3	0,083	0,022	0,082	0,156	0,156	-0,445	-0,445	-0,512
Specimen 4	0,150	0,266	0,001	0,140	0,001	0,140	-0,118	-0,296
Specimen 5	0,095	0,167	-0,307	-0,585	0,167	-0,307	-0,585	-0,703
Specimen 6*	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**
Specimen 7	0,043	0,274	0,137	0,096	0,137	0,096	-0,281	-0,563
Specimen 8**	0,026	0,151	0,176	0,254	-0,535	-0,487	-0,747	-0,793
Specimen 9	0,272	0,103	0,094	-0,111	-0,111	-0,355	-0,246	-0,356
Specimen 10	0,079	-0,078	0,032	-0,015	-0,352	-0,489	-0,202	-0,120

*Specimen 6 -Working length shorter than 1 mm.
** Specimen 8 – The specimen was kept in the sample for canal transportation and centering ability evaluations.

	Reciproc (25/08)				Reciproc (25/08)			
Sample	**Centering Ability in the apical third**				**Centering Ability in the coronal third**			
	1	2	3	4	4	3	2	1
Specimen 1	-0,300	0,554	0,615	0,438	0,093	0,010	0,270	0,820
Specimen2	0,688	0,025	0,269	0,231	0,447	0,191	0,089	-0,024
Specimen 3	0,447	0,914	0,573	0,505	0,505	0,129	0,127	0,050
Specimen 4	0,219	0,158	0,994	0,455	0,994	0,455	0,571	0,166
Specimen 5	0,080	0,440	0,100	0,110	0,440	0,100	0,110	0,010
Specimen 6*	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**
Specimen 7	0,578	0,021	0,507	0,611	0,507	0,611	0,247	0,029
Specimen 8**	0,683	0,156	0,054	0,136	0,163	0,273	0,026	0,220
Specimen 9	-0,030	0,512	0,602	0,580	0,580	0,215	0,337	0,276
Specimen 10	0,570	0,700	0,870	0,940	0,170	0,080	0,450	0,410

*Specimen 6 -Working length shorter than 1 mm
** Specimen 8 – The specimen was kept in the sample for canal transportation and centering ability evaluations

Sample	Prodesign R (25/06) Apical Transportation				Prodesign R (25/06) Coronal Transportation			
	1	2	3	4	4	3	2	1
Specimen 1	0,021	-0,104	-0,170	-0,401	-0,104	-0,170	-0,401	-0,369
Specimen2	-0,092	-0,038	0,005	0,138	0,138	0,016	-0,217	-0,491
Specimen 3	-0,066	0,025	0,449	0,147	0,165	0,203	-0,206	-0,425
Specimen 4	-0,236	0,017	0,026	0,039	0,039	0,158	-0,126	-0,268
Specimen 5	0,003	0,109	0,008	-0,093	-0,211	-0,591	-0,685	-0,477
Specimen 6*	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**
Specimen 7	0,027	-0,074	-0,050	0,066	-0,050	0,066	-0,275	-0,519
Specimen 8**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**
Specimen 9	-0,081	0,139	0,134	0,123	0,134	0,123	-0,087	-0,153
Specimen 10	0,267	0,002	0,090	0,037	0,091	-0,030	-0,189	-0,202

* Specimen 6 – This specimen was excluded because the file fractured
* *Specimen 8 – This specimen was excluded because the working length was shorter than 1 mm.

Sample	Prodesign R (25/06) Centering ability in the apical third				Prodesign R (25/06) Centering ability in the coronal third			
	1	2	3	4	4	3	2	1
Specimen 1	0,323	0,544	0,238	0,099	0,544	0,238	0,099	0,066
Specimen2	0,540	0,640	0,960	0,450	0,450	0,900	0,420	0,090
Specimen 3	0,550	0,800	0,160	0,230	0,430	0,040	0,460	0,160
Specimen 4	0,210	0,890	0,920	0,850	0,850	0,560	0,560	0,480
Specimen 5	0,920	0,250	0,950	0,570	0,200	0,000	0,010	0,140
Specimen 6*	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**
Specimen 7	0,570	0,610	0,690	0,700	0,690	0,700	0,310	0,040
Specimen 8**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**
Specimen 9	0,400	0,410	0,350	0,410	0,350	0,410	0,730	0,490
Specimen 10	0,030	0,960	0,290	0,610	0,070	0,660	0,140	0,060

* Specimen 6 – This specimen was excluded because the file fractured
* *Specimen 8 – This specimen was excluded because the working length was shorter than 1 mm.

Sample	Mtwo (25/06)				Mtwo (25/06)			
	Apical Transportation				**Coronal Transportation**			
	1	2	3	4	4	3	2	1
Specimen 1	-0,010	-0,021	0,267	0,162	0,162	-0,016	-0,390	-0,246
Specimen2	-0,066	-0,064	0,005	-0,020	-0,337	-0,482	-0,877	-0,857
Specimen 3	-0,192	-0,067	0,059	0,411	0,411	-0,033	-0,154	-0,468
Specimen 4	0,221	-0,184	-0,035	-0,035	0,204	-0,246	-0,429	-0,782
Specimen 5	-0,136	0,145	0,132	0,068	0,068	-0,136	-0,435	-0,461
Specimen 6	-0,006	0,134	-0,042	0,232	-0,213	-0,608	-0,578	-0,121
Specimen 7*	0,033	0,089	0,357	0,033	0,033	-0,383	-0,642	-0,807
Specimen 8	-0,016	0,252	0,121	-0,012	-0,166	-0,347	0,048	-0,014
Specimen 9	1,026	0,158	0,258	0,017	0,017	-0,329	-0,485	-0,486
Specimen 10**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**

* Specimen 7 – The specimen was kept in the sample for the canal transportation and centering ability evaluations.
* *Specimen 10 This specimen was excluded because the file fractured.

Sample	Mtwo (25/06)				Mtwo (25/06)			
	Centering ability in the apical third				**Centering ability in the coronal third**			
	1	2	3	4	4	3	2	1
Specimen 1	0,800	0,850	0,450	0,640	0,640	0,950	0,360	0,440
Specimen2	0,500	0,600	0,980	0,900	0,280	0,300	0,070	0,050
Specimen 3	0,150	0,260	0,160	-0,280	-0,280	0,880	0,330	0,100
Specimen 4	0,040	0,380	0,830	0,810	0,150	0,350	0,390	0,090
Specimen 5	0,060	0,240	0,450	0,800	0,800	0,670	0,340	0,050
Specimen 6	0,880	0,120	0,810	0,360	0,480	0,060	0,060	0,570
Specimen 7	0,800	0,527	0,003	0,829	0,829	0,210	0,040	0,070
Specimen 8	0,430	0,140	0,560	0,960	0,520	0,110	0,830	0,900
Specimen 9	-0,780	0,110	0,180	0,930	0,930	0,090	0,010	0,140
Specimen 10	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**

* Specimen 7 – The specimen was kept in the sample for the canal transportation and centering ability evaluations.
* *Specimen 10 This specimen was excluded because the file fractured.

Table 2 – The absolute values for the entire and apical volume after and before instrumentation of the MB2 canal for the systems evaluated.

	Reciproc (25/08)			Reciproc (25/08)		
	Apical Volume***			Whole Volume****		
Sample/Analisys	Initial Volume (mm^3)	Final Volume (mm^3)	Volume of Dentin Removed ***** (mm^3)	Initial Volume (mm^3)	Final Volume (mm^3)	Volume of Dentin Removed ***** (mm^3)
Specimen 1	**0,231**	**0,694**	0,463	**1,474**	**5,534**	4,060
Specimen2	**0,121**	**1,090**	0,969	**1,082**	**4,639**	3,557
Specimen 3	**0,608**	**1,171**	0,563	**0,566**	**2,015**	1,449
Specimen 4	**0,208**	**0,679**	0,471	**0,415**	**1,339**	0,924
Specimen 5	**0,164**	**0,493**	0,329	**0,184**	**0,699**	0,515
Specimen 6*	**null**	**null**	**null**	**null**	**null**	**null**
Specimen 7	**0,016**	**0,532**	0,516	**0,184**	**1,468**	1,284
Specimen 8**	**0,190**	**0,781**	0,591	**0,952**	**3,557**	2,605
Specimen 9	**0,113**	**0,513**	0,400	**0,485**	**1,834**	1,349
Specimen 10	**0,025**	0,487	0,462	**0,380**	2,524	2,144

*Specimen 6 –The Working length was shorter than 1 mm, and so the specimen was excluded.
** Specimen 8 – The specimen had a coroal perforation, in the danger zone, but it was kept in the sample because the region of interest could be bound from the initial anatomic external root.

***Mean volume in apical third was calculated between 1 millimeter short from the apex to 4 millimeters distant to the apex;
****Mean volume in all thirds was calculated from apical foramen to the coronal third (furcation area).

*****Volume of dentin removed was calculated by subtracting the initial (uninstrumented) canal volume from the final (instrumented) canal volume.

	Prodesign R (25/06)			Prodesign R (25/06)		
	Apical Volume***			Whole Volume****		
Sample/Analisys	Initial Volume (mm^3)	Final Volume (mm^3)	Volume of Dentin Removed ***** (mm^3)	Initial Volume (mm^3)	Final Volume (mm^3)	Volume of Dentin Removed ***** (mm^3)
Specimen 1	0,242	0,659	0,417	0,339	0,898	0,559
Specimen2	0,243	0,941	0,698	0,335	1,416	1,081
Specimen 3	0,196	0,464	0,268	0,782	1,754	0,972
Specimen 4	0,044	0,515	0,471	0,340	1,812	1,472
Specimen 5	0,104	0,548	0,444	0,202	2,055	1,853
Specimen 6*	null	null	null	null	null	null
Specimen 7	0,001	0,161	0,160	0,036	0,599	0,563
Specimen 8 **	**null**	**null**	**null**	**null**	**null**	**null**
Specimen 9	0,180	0,456	0,276	0,346	1,206	0,860
Specimen 10	0,075	0,197	0,122	0,449	1,228	0,779

* Specimen 6 – This specimen was excluded because the file fractured.

* *Specimen 8 – This specimen was excluded because the working length was shorter than 1 mm.

***Mean volume in apical third was calculated between 1 millimeter short from the apex to 4 millimeters distant to the apex;
****Mean volume in all thirds was calculated from apical foramen to the coronal third (furcation area).

*****Volume of dentin removed was calculated by subtracting the initial (uninstrumented) canal volume from the final (instrumented) canal volume.

Sample	Mtwo (25/06) Apical Volume***			Mtwo (25/06) Whole Volume****		
	Initial Volume (mm^3)	Final Volume (mm^3)	Volume of Dentin Removed ***** (mm^3)	Final Volume (mm^3)	Initial Volume (mm^3)	Volume of Dentin Removed ***** (mm^3)
Specimen 1	0,046	0,410	0,364	1,897	4,646	2,749
Specimen2	0,123	0,362	0,239	0,390	2,397	2,007
Specimen 3	0,597	1,838	1,241	0,777	1,499	0,722
Specimen 4	0,042	0,607	0,565	1,291	3,673	2,382
Specimen 5	0,026	0,595	0,569	0,235	1,842	1,607
Specimen 6	0,000	0,153	0,153	0,365	1,904	1,539
Specimen 7*	0,222	0,533	0,311	0,583	2,241	1,658
Specimen 8	0,207	0,667	0,460	0,665	2,212	1,547
Specimen 9	0,328	0,622	0,294	0,819	2,184	1,365
Specimen 10**	**null**	**null**	**null**	**null**	**null**	**null**

* Specimen 7 – The specimen had a coroal perforation, in the danger zone, but it was kept in the sample because the region of interst could bound the initial anatomic external root.

* *Specimen 10- This specimen was excluded because the file fractured.

***Mean volume in apical third was calculated between 1 millimeter short from the apex to 4 millimeters distant to the apex;

****Mean volume in all thirds was calculated from apical foramen to the coronal third (furcation area).

*****Volume of dentin removed was calculated by subtracting the initial (uninstrumented) canal volume from the final (instrumented) canal volume.

Table 3 – The absolute values for the shaping time (s) after instrumentation and the number of patenciable MB2 canals for the systems evaluated.

	Reciproc (25/08)		ProdesignR (25/06)		Mtwo (25/06)	
Sample	Shaping time(s)	Patenciable MB2 canals	Shaping time(s)	Patenciable MB2 canals	Shaping time(s)	Patenciable MB2 canals
Specimen 1	171	Yes	216	Yes	176	Yes
Specimen2	147	Yes	188	Yes	100	Yes
Specimen 3	128	Yes	195	No	135	Yes
Specimen 4	163	Yes	237	Yes	197	Yes
Specimen 5	128	Yes	245	Yes	196	No
Specimen 6	*a	No	*b	NO	238	No
Specimen 7	102	No	248	No	130	Yes
Specimen 8	95	Yes	null	No	158	No
Specimen 9	99	No	208	No	148	Yes
Specimen 10	118	No	219	No	*b	No

*a = *Specimen 6 in the reciproc group –The Working length was shorter than 1 mm, and so the specimen was excluded.
*b = The file fractured during shaping procedure.

Table 4. The absolute values for Thickness measures (mm) of distal dentin wall of coronal third in the MB2 canal of maxillary first molars for the systems evaluated

Sample	Reciproc (25/08) Anatomical root thickness (Y1)***				Reciproc (25/08) Remaining Dentin Thickness (Y2)****				Reciproc (25/08) Removal of distal dentin wall (Y1- Y2)*****			
	1	2	3	4	1	2	3	4	1	2	3	4
Specimen 1	1,006	1,043	1,165	1,058	0,274	0,274	0,416	0,650	0,732	0,769	0,749	0,408
Specimen2	**1,193**	**1,198**	1,464	1,274	0,804	0,617	0,743	0,477	0,389	0,581	0,721	0,797
Specimen 3	**0,794**	**1,06**	1,128	1,277	0,635	0,549	0,618	0,738	0,159	0,511	0,510	0,539
Specimen 4	**1,024**	**0,867**	1,024	1,064	0,847	0,750	0,749	0,709	0,177	0,117	0,275	0,355
Specimen 5	**0,758**	**0,846**	1,005	1,184	0,626	0,503	0,344	0,479	0,132	0,343	0,661	0,705
Specimen 6*	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**
Specimen 7	**0,699**	**0,739**	0,875	0,946	0,558	0,588	0,502	0,366	0,141	0,151	0,373	0,58
Specimen 8**	**0,710**	**0,670**	0,767	1,011	0,071	0	0	0	0,639	0,670	0,767	1,011
Specimen 9	**1,304**	**1,288**	1,246	1,172	1,040	0,836	0,875	0,68	0,264	0,452	0,371	0,492
Specimen 10	**1,480**	**1,862**	1,500	1,64	1,058	1,332	1,130	1,438	0,422	0,530	0,370	0,202

*Specimen 6 -Working length shorter than 1 mm.
** Specimen 8 – The specimen was kept in the sample and the thickness was considered zero because the perfuration at coronal third.
***Y1 means the shortest distance from the edge of uninstrumented MB2 canal to the distal portion of the mesiobuccal root.
****Y2 means respectively the shortest distance from the edge instrumented MB2 canal to the distal portion of the mesiobuccal root.
*****Y1-Y2 means the amount of dentin removed after instrumentantion.

Sample	Prodesign R (25/06) Anatomical root thickness (Y1)***				Prodesign R (25/06) Remaining Dentin Thickness (Y2)****				Prodesign R (25/06) Removal of distal dentin wall (Y1- Y2)*****			
Specimen 1	0,800	0,761	0,928	0,947	0,572	0,538	0,483	0,552	0,228	0,223	0,445	0,395
Specimen2	0,816	0,893	0,951	1,047	0,701	0,754	0,579	0,505	0,115	0,139	0,372	0,542
Specimen 3	1,237	1,042	1,372	1,329	1,110	1,033	0,988	0,904	0,127	0,009	0,384	0,425
Specimen 4	1,221	1,118	1,192	1,276	1,004	0,917	0,908	0,765	0,217	0,201	0,284	0,511
Specimen 5	0,593	0,849	0,947	1,244	0,330	0,256	0,254	0,692	0,263	0,593	0,693	0,552
Specimen 6*	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**
Specimen 7	0,804	0,804	0,899	0,892	0,644	0,652	0,502	0,351	0,160	0,152	0,397	0,541
Specimen 8 **	0,817	0,889	1,229	0,995	0,804	0,699	0,769	0,782	0,013	0,190	0,460	0,213
Specimen 9	0,672	0,643	0,902	0,898	0,599	0,557	0,579	0,599	0,073	0,086	0,323	0,299
Specimen 10	0,749	0,811	0,802	0,940	0,742	0,723	0,582	0,724	0,007	0,088	0,220	0,216

* Specimen 6 – This specimen was excluded because the file fractured

* *Specimen 8 – This specimen was excluded because the working length was shorter than 1 mm.

***Y1 means the shortest distance from the edge of uninstrumented MB2 canal to the distal portion of the mesiobuccal root.

****Y2 means respectively the shortest distance from the edge instrumented MB2 canal to the distal portion of the mesiobuccal root.

*****Y1-Y2 means the amount of dentin removed after instrumentantion.

	Mtwo (25/06)				Mtwo (25/06)				Mtwo (25/06)			
Sample	Anatomical root thickness (Y1)***				Remaining Dentin Thickness (Y2)****				Removal of distal dentin wall (Y1- Y2)*****			
Specimen 1	0,670	0,919	1,084	0,891	0,382	0,574	0,474	0,455	0,288	0,345	0,610	0,436
Specimen2	1,013	1,001	1,027	0,947	0,545	0,308	0,079	0,044	0,468	0,693	0,948	0,903
Specimen 3	1,204	1,356	1,218	1,362	1,295	1,090	0,989	0,842	-0,091	0,266	0,229	0,520
Specimen 4	1,420	1,539	1,712	1,727	1,383	1,159	1,014	0,865	0,037	0,380	0,698	0,862
Specimen 5	1,180	1,035	1,050	1,295	0,904	0,629	0,388	0,810	0,276	0,406	0,662	0,485
Specimen 6	0,899	0,962	1,134	0,927	0,487	0,318	0,517	0,648	0,412	0,644	0,617	0,279
Specimen 7*	0,717	0,571	0,671	0,868	0,557	0,088	0,000	0,000	0,160	0,483	0,671	0,868
Specimen 8	1,076	0,805	0,712	0,660	0,731	0,416	0,473	0,522	0,345	0,389	0,239	0,138
Specimen 9	1,095	0,939	1,034	1,422	0,858	0,579	0,545	0,855	0,237	0,360	0,489	0,567
Specimen 10**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**	**null**

* Specimen 7 – The specimen was kept in the sample and the thickness was considered zero because the perfuration at coronal Third

* *Specimen 10- This specimen was excluded because the file fractured

***Y1 means the shortest distance from the edge of uninstrumented MB2 canal to the distal portion of the mesiobuccal root.

****Y2 means respectively the shortest distance from the edge instrumented MB2 canal to the distal portion of the mesiobuccal root.

*****Y1-Y2 means the amount of dentin removed after instrumentantion.

APPENDIX C

Table 1- Statistical analysis of the data evaluated in the MB2 canal preparation with the three systems evaluated

Mesiobuccal Root –Coronal Dentin Thickness

	2) Y2			
	4	3	2	1
Reciproc	n.s	n.s	n.s	n.s
Prodesign R	n.s	n.s	n.s	n.s
Mtwo	n.s	n.s	n.s	n.s
p	**0,985**	**0,656**	**0,519**	**0,493**

* **n.s** No statistical differences were found in the intergroup comparison at the same level (Kruskal-Wallis and Dunn. P>0.05).

Transportation

	Apical Transportation					Coronal Transportation			
System/Level	**1**	**2**	**3**	**4**		**4**	**3**	**2**	**1**
Reciproc	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s
Prodesign R	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s
Mtwo	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s
p	**0,134**	**0,384**	**0,642**	**0,899**		**0,433**	**0,057**	**0,249**	**0,698**

* **n.s** No statistical differences were found in the intergroup comparison at the same level (Kruskal-Wallis and Dunn. P>0.05).

Centering Ability

	Centering Ability of Apical Third					Centering Ability of Coronal Third			
System/Level	**1**	**2**	**3**	**4**		**4**	**3**	**2**	**1**
Reciproc	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s
Prodesign R	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s
Mtwo	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s
p	**0,951**	0,081	0,840	0,846		0,461	0,399	0,650	0,818

* **n.s** No statistical differences were found in the intergroup comparison at the same level (Kruskal-Wallis and Dunn. P>0.05).

Intragroups Comparisson of Initial and Final Volumes

	Apical Volume				Whole Volume		
	Initial Volume** x Final Volume***				Initial Volume** x Final Volume***		
System	**Reciproc**	**Prodesign R**	**Mtwo**		**Reciproc**	**Prodesign R**	**Mtwo**
Reciproc	**Initial Volume ≠ Final Volume**	------------	------------		**Initial Volume ≠ Final Volume**	------------	------------
Prodesign R	------------	**Initial Volume ≠ Final Volume**	------------		------------	**Initial Volume ≠ Final Volume**	------------
Mtwo	------------	------------	**Initial Volume ≠ Final Volume**		------------	------------	**Initial Volume ≠ Final Volume**
p	0,0039	0,0078	0,0039		0,0039	**0,0078**	**0,0039**

*** n.s =** No statistical differences were found in the intergroup comparison at the same level (Kruskal-Wallis and Dunn. P>0.05).
** initial apical volume is the anatomic volum of the canal.
*** Final Apical Volume is the apical volume between 1 mm and 4 mm shorter than apex after shaping procedures.

Intergroups Comparisson of Initial and Final Apical Volumes

	Initial Apical Volume**				Final Apical Volume***				Volume of Dentin Removed****		
System	**Reciproc**	**Prodesign R**	**Mtwo**		**Reciproc**	**Prodesign R**	**Mtwo**		**Reciproc**	**Prodesign R**	**Mtwo**
Reciproc	-----------	***ns**	***ns**		-----------	***ns**	***ns**		-----------	***ns**	***ns**
Prodesign R	***ns**	-----------	***ns**		***ns**	-----------	***ns**		***ns**	-----------	***ns**
Mtwo	***ns**	***ns**	-----------		***ns**	***ns**	-----------		***ns**	***ns**	-----------
p	**0,960**	**0,906**	**0,960**		**0,229**	**0,229**	**0,229**		**0,149**		

*** n.s =** No statistical differences were found in the intergroup comparison at the same level (Kruskal-Wallis and Dunn. P>0.05)
** Initial Apical Volume is the apical volume between 1 mm and 4 mm shorter than apex before shaping procedures.
*** Final Apical Volume is the apical volume between 1 mm and 4 mm shorter than apex after shaping procedures.
**** The volume of dentin removed means the final volume substracted by the initial volume.

Intergroups Comparisson of Initial and Final Whole Volumes

	Initial Whole Volume***				Final Whole Volume****				Volume of Dentin Removed*****		
System	**Reciproc**	**Prodesign R**	**Mtwo**		**Reciproc**	**Prodesign R**	**Mtwo**		**Reciproc**	**Prodesign R**	**Mtwo**
Reciproc	----------	***ns**	***ns**		----------	***ns**	***ns**		----------	***ns**	***ns**
Prodesign R	***ns**	-----------	***ns**		***ns**	-----------	**PDR≠MO**		***ns**	-----------	***ns**
Mtwo	***ns**	***ns**	----------		***ns**	**MO≠ PDR**	-----------		***ns**	***ns**	----------
p	**0,075**	**0,075**	**0,075**		***ns**	**0,014**	**0,014**		0,062	0,062	0,062

*** n.s =** No statistical differences were found in the intergroup comparison at the same level (Kruskal-Wallis and Dunn. P>0.05)
** **≠ **means that there were** statistical differences in the intergroup comparison at the same level (Kruskal-Wallis and Dunn. P<0.05)

*** Initial Whole Volume is the entire volume of the canal before shaping procedures.
**** Final Whole Volume is the entire volume of the canal before shaping procedures.
***** The volume of dentin removed means the final volume substracted by the initial volume.

Intergroups Comparisson of Working Time

	Working time**		
System	**Reciproc**	**Prodesign R**	**Mtwo**
Reciproc	-----------	**REC≠PDR**	***ns**
Prodesign R	**PDR≠REC**	-----------	***ns**
Mtwo	***ns**	***ns**	-----------
p	0,0006	0,0006	***ns**

*** n.s =** No statistical differences were found in the intergroup comparison at the same level (Kruskal-Wallis and Dunn. P>0.05)
****≠ means that there were** statistical differences in the intergroup comparison at the same level (Kruskal-Wallis and Dunn. P<0.05)

APPENDIX D

The absolute values recorded of the evaluation of the mesiobuccal canal of maxillary molars prepared with three heat-treated NiTi Alloys

	Transportation – Mesiobuccal Canal - Reciproc								
	Apical Transportation					Coronal Transportation			
Specimen/ Level	1	2	3	4		4	3	2	1
1	-0,024	0,157	0,018	-0,139		-0,156	-0,276	-0,278	-0,681
2	0,142	0,355	0,434	-0,302		-0,302	-0,480	-0,580	-0,962
3	0,015	0,052	0,061	0,033		-0,114	-0,152	-0,402	-0,517
4	0,065	-0,003	-0,160	-0,458		-0,160	-0,458	-0,261	0,067
5	0,052	-0,016	-0,209	-0,533		-0,209	-0,533	-0,370	-0,089
6	-0,166	0,234	0,081	0,061		-0,064	-0,079	-0,355	-0,305
7	-0,003	-0,238	-0,097	-0,102		-0,097	-0,102	0,132	0,070
8	0,052	0,109	-0,299	0,066		0,109	-0,299	0,066	-0,218
9	0,072	0,078	0,256	0,291		0,291	0,022	-0,658	-0,443
10	0,155	-0,107	0,129	-0,182		-0,182	-0,056	-0,421	-0,175
11	0,023	-0,072	0,003	0,106		-0,080	-0,325	-0,555	-0,448
12	0,036	-0,027	-0,030	-0,204		-0,030	-0,204	-0,235	-0,074
13	-0,384	-0,353	-0,058	-0,225		-0,353	-0,058	-0,225	-0,259
14	-0,180	-0,037	-0,010	-0,029		-0,010	-0,029	-0,060	-0,354
15	0,118	-0,042	0,054	-0,149		-0,149	-0,153	-0,087	-0,400

	Transportation – Mesiobuccal Canal – Hyflex CM								
	Apical Transportation					Coronal Transportation			
Specimen/ Level	1	2	3	4		4	3	2	1
1	0,307	0,203	0,365	0,228		0,203	0,365	0,228	0,097
2	0,059	0,056	0,112	0,197		-0,097	-0,160	-0,233	-0,408
3	0,083	0,076	0,007	0,002		0,007	0,002	-0,296	-0,412
4	-0,052	-0,211	0,238	0,208		0,237	0,028	-0,301	-0,425
5	-0,049	0,024	0,083	0,084		0,042	0,231	-0,052	-0,200
6	0,224	0,187	0,204	0,175		0,175	-0,305	-0,559	-0,763
7	0,118	0,247	0,192	0,033		0,033	-0,302	-0,612	-0,477
8	0,169	0,185	0,126	0,127		0,126	0,127	-0,305	-0,535
9	0,083	-0,086	0,070	0,176		-0,027	-0,294	-0,113	-0,576
10	-0,088	-0,071	0,182	0,073		0,073	0,044	-0,136	-0,255
11	0,074	0,227	0,184	0,026		0,184	0,026	-0,124	-0,239
12	0,092	0,336	0,239	0,042		0,239	0,042	-0,332	-0,423
13	-0,203	-0,065	0,078	0,333		-0,366	-0,471	-0,916	-0,836
14	0,148	0,420	-0,034	-0,082		-0,082	-0,288	-0,417	-0,324
15	0,151	0,043	0,332	0,051		0,031	0,016	-0,321	-0,080

	Transportation – Mesiobuccal Canal - TFA								
	Apical Transportation					Coronal Transportation			
Specimen/ Level	1	2	3	4		4	3	2	1
1	-0,127	-0,102	0,068	0,084		-0,094	-0,192	-0,214	-0,338
2	-0,069	0,249	0,166	0,084		0,185	-0,334	-0,224	0,032
3	0,188	0,045	0,097	-0,013		0,097	-0,013	-0,332	-0,067
4	-0,096	-0,055	0,119	-0,190		0,020	0,006	-0,228	-0,174
5	0,134	0,033	0,049	0,006		0,006	0,117	-0,209	-0,121
6	-0,006	-0,130	-0,045	-0,126		-0,060	0,175	-0,288	-0,547
7	0,033	-0,086	-0,004	0,027		0,027	0,022	-0,113	0,102
8	0,091	0,013	0,056	0,065		-0,207	-0,339	-0,493	-0,220
9	-0,102	-0,069	0,081	-0,208		-0,208	-0,016	-0,071	-0,432
10	0,164	0,068	-0,144	0,050		-0,144	0,050	-0,119	-0,196
11	0,103	-0,003	0,121	0,075		0,075	0,085	-0,250	-0,632
12	0,029	-0,068	0,093	0,181		0,104	-0,266	-0,409	-0,275
13	0,071	0,060	0,008	0,003		0,003	0,090	-0,018	-0,406
14	0,027	-0,066	0,067	0,092		0,067	0,092	0,010	-0,263
15	-0,110	-0,111	0,020	0,018		0,007	0,020	-0,387	-0,150

	Centering Ability – Mesiobuccal Canal - Reciproc								
	Apical Third					Coronal Third			
Specimen/ Level	1	2	3	4		4	3	2	1
1	0,893	0,437	0,922	0,620		0,480	0,287	-0,188	-0,097
2	0,625	0,364	-0,229	0,283		0,283	0,204	0,167	0,076
3	0,571	0,714	0,667	0,800		0,444	0,318	0,113	0,073
4	-0,161	0,953	0,495	0,124		0,495	0,124	0,389	0,547
5	0,756	0,937	0,337	0,057		0,337	0,057	0,228	0,717
6	0,381	0,029	0,603	0,365		0,247	0,484	0,108	0,437
7	0,850	0,337	0,520	0,602		0,520	0,602	0,374	0,830
8	0,766	0,473	0,035	0,777		0,473	0,035	0,777	0,476
9	0,258	0,559	0,177	0,105		0,105	0,912	-0,134	0,260
10	0,320	0,509	0,122	-0,058		-0,058	0,758	-0,531	0,379
11	0,736	0,507	0,571	0,086		0,490	0,375	0,159	0,147
12	0,493	0,682	0,694	0,368		0,694	0,368	0,270	0,321
13	0,000	0,201	0,836	0,492		0,201	0,836	0,492	0,318
14	0,490	0,845	0,967	0,918		0,967	0,918	0,815	0,295
15	0,407	0,750	0,733	0,374		0,374	0,354	0,707	0,307

	Centering Ability – Mesiobuccal Canal – Hyflex CM								
	Apical Third					Coronal Third			
Specimen/ Level	1	2	3	4		4	3	2	1
1	0,225	0,280	0,264	0,426		0,280	0,264	0,426	0,696
2	0,715	0,684	0,371	0,254		0,732	0,495	0,388	0,179
3	0,591	0,345	0,952	0,985		0,952	0,985	0,290	0,140
4	0,728	0,315	0,176	0,232		0,275	0,893	0,283	0,175
5	0,602	0,314	0,366	0,660		0,725	0,192	0,756	0,398
6	0,319	0,327	0,073	0,490		0,490	0,437	0,223	0,122
7	0,637	0,372	0,553	0,900		0,900	0,267	0,165	0,086
8	0,265	0,254	0,512	0,455		0,512	0,455	0,234	0,156
9	0,500	0,252	0,507	0,011		0,886	0,476	0,511	0,002
10	0,453	0,474	0,463	0,716		0,716	0,831	0,603	0,400
11	0,584	0,366	0,416	0,824		0,416	0,824	0,541	0,452
12	0,080	0,032	0,278	0,775		0,278	0,775	0,363	0,188
13	0,347	0,739	0,755	0,163		0,344	0,218	0,083	0,050
14	0,164	0,039	0,818	0,733		0,733	0,046	0,054	0,117
15	0,518	0,753	0,057	0,788		0,897	0,946	0,250	0,807

	Centering Ability – Mesiobuccal Canal - TFA								
	Apical Third					Coronal Third			
Specimen/ level	1	2	3	4		4	3	2	1
1	0,093	-0,052	0,485	0,700		0,628	0,063	0,189	0,056
2	0,420	0,129	0,320	0,616		-0,423	0,197	0,164	0,814
3	0,113	0,526	0,134	0,911		0,134	0,911	0,067	0,489
4	0,143	0,495	0,399	0,069		0,655	0,982	0,389	0,453
5	0,076	0,697	0,629	0,929		0,929	0,193	0,324	0,280
6	0,727	0,116	0,477	0,100		0,580	0,070	0,344	0,068
7	0,777	0,211	0,957	0,824		0,824	0,796	0,386	0,404
8	0,571	0,910	0,731	0,558		0,361	0,261	0,196	0,451
9	0,266	0,504	0,500	0,246		0,246	0,920	0,603	-0,252
10	0,248	0,752	0,452	0,730		0,452	0,730	0,485	0,497
11	0,383	0,975	-0,071	0,623		0,623	0,465	0,415	0,100
12	0,000	0,236	0,000	0,000		0,000	0,307	0,302	0,390
13	0,489	0,589	0,932	0,980		0,980	0,565	0,926	0,022
14	0,308	0,377	0,396	0,418		0,396	0,418	0,946	0,346
15	0,412	0,560	0,835	0,845		0,887	0,826	0,067	0,180

	Reciproc – Mesiobuccal Canal								
	Apical Volume(mm³)					Whole Volume (mm³)			
Specimen/analysis	Initial Volume (mm³)	Final Volume (mm³)	Removed Volume (mm³)	Percentage of increased volume (mm³)		Initial Volume (mm³)	Final Volume (mm³)	Removed Volume (mm³)	Percentage of increased volume (mm³)
1	0,097	0,784	0,687	708,247		0,340	1,785	1,445	425,000
2	0,199	1,303	1,104	554,774		0,513	3,472	2,959	576,803
3	0,264	0,578	0,314	118,939		1,259	2,668	1,409	111,914
4	0,414	0,826	0,412	99,517		0,997	1,882	0,885	88,766
5	0,537	1,544	1,007	187,523		1,004	3,257	2,253	224,402
6	0,15	0,729	0,579	386,000		0,992	3,099	2,107	212,399
7	0,576	1,106	0,530	92,014		1,268	2,459	1,191	93,927
8	0,327	0,877	0,550	168,196		0,618	1,446	0,828	133,981
9	0,525	0,644	0,119	22,667		1,262	2,113	0,851	67,433
10	0,234	0,651	0,417	178,205		0,756	1,879	1,123	148,545
11	0,718	0,938	0,220	30,641		1,956	3,612	1,656	84,663
12	0,44	0,585	0,149	34,174		0,988	1,331	0,343	34,717
13	0,10	1,118	1,022	1.064,583		0,156	1,873	1,717	1100,641
14	0,436	1,064	0,628	144,037		0,913	2,305	1,392	152,464
15	0,453	0,667	0,214	47,241		1,576	2,359	0,783	49,683

	Hyflex CM – Mesiobuccal Canal								
	Apical Volume(mm³)					Whole Volume (mm³)			
Specimen/analysis	Initial Volume (mm³)	Final Volume (mm³)	Removed Volume (mm³)	Percentage of increased volume (mm³)		Initial Volume (mm³)	Final Volume (mm³)	Removed Volume (mm³)	Percentage of increased volume (mm³)
1	0,159	0,941	0,782	491,824		0,255	1,489	1,234	483,9
2	0,785	1,301	0,516	65,732		2,759	5,139	2,38	86,3
3	0,365	0,622	0,257	70,411		0,799	1,602	0,803	100,5
4	0,508	0,813	0,305	60,118		1,118	3,544	2,426	217,0
5	0,417	0,755	0,338	81,055		2,695	4,538	1,843	68,4
6	0,323	1,103	0,780	241,486		0,945	3,503	2,558	270,7
7	0,081	0,968	0,887	1095,062		0,395	3,015	2,62	663,3
8	0,523	0,637	0,114	21,797		1,049	1,723	0,674	64,3
9	0,687	0,948	0,261	37,991		2,787	4,304	1,517	54,4
10	0,188	0,567	0,379	201,596		0,603	1,955	1,352	224,2
11	0,424	0,778	0,354	83,491		0,852	1,677	0,825	96,8
12	1,263	1,732	0,469	37,134		2,552	3,91	1,36	53,3
13	0,081	0,451	0,370	456,790		0,87	5,11	4,24	485,9
14	0,651	1,265	0,614	94,316		2,239	4,086	1,85	82,5
15	0,107	0,639	0,532	497,196		0,713	2,611	1,90	266,2

	TFA – Mesiobuccal Canal								
	Apical Volume(mm^3)					Whole Volume (mm^3)			
Specimen/analysis	Initial Volume (mm^3)	Final Volume (mm^3)	Removed Volume (mm^3)	Percentage of increased volume (mm^3)		Initial Volume (mm^3)	Final Volume (mm^3)	Removed Volume (mm^3)	Percentage of increased volume (mm^3)
1	0,781	0,792	0,011	1,408		3,672	4,136	0,464	12,636
2	0,016	0,167	0,151	943,750		0,692	1,417	0,725	104,769
3	0,251	0,471	0,220	87,649		0,667	1,242	0,575	86,207
4	0,212	0,328	0,116	54,717		1,496	2,309	0,813	54,345
5	0,313	0,364	0,051	16,294		1,197	1,383	0,186	15,539
6	0,673	0,704	0,031	4,606		3,620	3,961	0,341	9,420
7	0,367	0,414	0,047	12,807		1,201	1,360	0,159	13,239
8	0,419	0,599	0,180	42,959		2,717	4,104	1,387	51,049
9	0,094	0,358	0,264	280,851		0,357	1,408	1,051	294,398
10	0,137	0,518	0,381	278,102		0,469	1,344	0,875	186,567
11	0,478	0,729	0,251	52,510		1,326	2,445	1,119	84,389
12	0,336	0,445	0,109	32,440		2,159	3,620	1,461	67,670
13	0,299	0,502	0,203	67,893		0,793	1,277	0,484	61,034
14	0,483	0,558	0,075	15,528		1,024	1,323	0,299	29,199
15	0,341	0,359	0,018	5,279		1,360	1,742	0,382	28,088

	Reciproc - Mesiobuccal Canal													
	Apical – Mesial Side					Apical – Mesial Side					Apical – Mesial Side			
	Anatomical Dentin Thickness (X1)					Remaining Dentin Thickness (X2)					Dentin Removed (X1-X2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	0,778	0,906	1,001	1,239		0,577	0,627	0,770	1,012		0,201	0,279	0,231	0,227
2	1,262	1,462	1,435	1,496		0,883	0,904	1,082	1,377		0,379	0,558	0,353	0,119
3	1,059	1,301	1,404	1,52		1,024	1,119	1,221	1,355		0,035	0,182	0,183	0,165
4	0,816	0,841	0,973	0,995		0,807	0,78	0,816	0,93		0,009	0,061	0,157	0,065
5	1,929	1,763	1,633	1,535		1,716	1,525	1,527	1,503		0,213	0,238	0,106	0,032
6	1,21	1,548	1,681	1,747		1,108	1,307	1,477	1,651		0,102	0,241	0,204	0,096
7	1,447	1,714	1,755	1,718		1,43	1,593	1,65	1,564		0,017	0,121	0,105	0,154
8	1,409	1,529	1,816	1,968		1,187	1,322	1,805	1,672		0,222	0,207	0,011	0,296
9	1,423	1,33	1,342	1,312		1,326	1,153	1,031	0,987		0,097	0,177	0,311	0,325
10	1,734	1,527	1,578	1,166		1,506	1,416	1,431	1,176		0,228	0,111	0,147	0,010
11	0,822	0,777	0,84	0,954		0,735	0,703	0,833	0,838		0,087	0,074	0,007	0,116
12	1,12	1,168	1,164	1,164		1,049	1,11	1,096	1,045		0,071	0,058	0,068	0,119
13	1,095	0,976	1,241	1,241		1,094	0,887	0,946	1,023		0,001	0,089	0,295	0,218
14	1,213	1,247	1,39	1,182		1,038	1,045	1,095	0,857		0,175	0,202	0,295	0,325
15	0,651	0,724	0,946	0,828		0,452	0,598	0,744	0,739		0,199	0,126	0,202	0,089

	Reciproc- Mesiobuccal Canal													
	Apical – Distal Side					Apical – Distal Side					Apical – Distal Side			
	Anatomical Dentin Thickness (Y1)					Remaining Dentin Thickness (Y2)					Dentin Removed (Y1-Y2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	0,826	1,128	1,319	1,557		0,601	1,006	1,106	1,191		0,225	0,122	0,213	0,366
2	1,472	1,628	1,403	1,57		1,235	1,425	1,484	1,149		0,237	0,203	-0,081	0,421
3	1,148	1,436	1,703	1,727		1,128	1,306	1,581	1,595		0,020	0,130	0,122	0,132
4	1,137	0,84	1,077	1,193		1,193	0,776	0,76	0,67		0,056	0,064	0,317	0,523
5	1,568	1,47	1,437	1,502		1,407	1,216	1,122	0,937		0,161	0,254	0,315	0,565
6	1,3	1,339	1,512	1,709		1,032	1,332	1,389	1,674		0,268	0,007	0,123	0,035
7	2,328	2,295	2,164	1,877		2,308	1,936	1,962	1,621		0,020	0,359	0,202	0,256
8	2,322	2,754	3,659	1,536		2,152	2,656	3,349	1,306		0,170	0,098	0,310	0,230
9	1,22	1,395	1,391	1,438		1,195	1,296	1,336	1,404		0,025	0,099	0,055	0,034
10	1,103	1,62	1,468	1,62		1,030	1,402	1,45	1,448		0,073	0,218	0,018	0,172
11	0,655	0,963	1,015	0,962		0,591	0,817	1,011	0,952		0,064	0,146	0,004	0,010
12	1,287	1,336	1,27	1,406		1,252	1,251	1,172	1,083		0,035	0,085	0,098	0,323
13	1,361	1,507	1,625	1,684		0,976	1,065	1,272	1,241		0,385	0,442	0,353	0,443
14	1,271	1,126	1,015	1,152		0,916	0,887	0,71	0,798		0,355	0,239	0,305	0,354
15	1,093	1,258	1,272	1,302		1,012	1,09	1,124	1,064		0,081	0,168	0,148	0,238

	Hyflex CM - Mesiobuccal Canal													
	Apical – Mesial Side					Apical – Mesial Side					Apical – Mesial Side			
	Anatomical Dentin Thickness (X1)					Remaining Dentin Thickness (X2)					Dentin Removed (X1-X2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	1,782	1,516	1,484	1,472		1,386	1,234	0,988	1,075		0,396	0,282	0,496	0,397
2	1,419	1,389	1,331	1,418		1,212	1,212	1,153	1,154		0,207	0,177	0,178	0,264
3	1,300	1,213	1,212	1,292		1,097	1,097	1,065	1,162		0,203	0,116	0,147	0,130
4	1,000	1,191	1,257	1,328		0,861	1,094	0,968	1,057		0,139	0,097	0,289	0,271
5	0,919	1,000	1,574	1,968		0,845	0,965	1,443	1,721		0,074	0,035	0,131	0,247
6	1,026	1,059	1,093	1,243		0,697	0,781	0,873	0,9		0,329	0,278	0,220	0,343
7	0,928	0,860	0,991	1,020		0,603	0,467	0,561	0,69		0,325	0,393	0,430	0,330
8	0,940	1,024	1,094	1,237		0,71	0,776	0,836	1,004		0,230	0,248	0,258	0,233
9	1,162	1,090	1,218	1,212		0,997	1,061	1,076	1,034		0,165	0,029	0,142	0,178
10	0,875	1,034	1,259	1,184		0,802	0,97	0,92	0,927		0,073	0,064	0,339	0,257
11	1,319	1,630	1,627	1,444		1,141	1,272	1,312	1,296		0,178	0,358	0,315	0,148
12	1,455	1,685	1,495	1,576		1,355	1,338	1,164	1,389		0,100	0,347	0,331	0,187
13	1,090	1,338	1,426	1,485		0,982	1,154	1,108	1,087		0,108	0,184	0,318	0,398
14	0,650	0,947	0,906	1,125		0,473	0,51	0,753	0,900		0,177	0,437	0,153	0,225
15	0,939	1,108	1,237	1,140		0,626	0,934	0,885	0,900		0,313	0,174	0,352	0,240

	Hyflex CM- Mesiobuccal Canal													
	Apical – Distal Side					Apical – Distal Side					Apical – Distal Side			
	Anatomical Dentin Thickness (Y1)					Remaining Dentin Thickness (Y2)					Dentin Removed (Y1-Y2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	0,918	1,216	1,569	1,420		0,829	1,137	1,438	1,251		0,089	0,079	0,131	0,169
2	1,064	1,274	1,433	1,011		0,916	1,153	1,367	0,944		0,148	0,121	0,066	0,067
3	1,129	1,488	1,335	1,247		1,009	1,448	1,195	1,119		0,120	0,040	0,140	0,128
4	1,421	1,541	1,338	1,278		1,230	1,233	1,287	1,215		0,191	0,308	0,051	0,063
5	1,436	1,338	1,639	1,745		1,313	1,327	1,591	1,582		0,123	0,011	0,048	0,163
6	0,845	0,991	1,009	1,041		0,740	0,900	0,993	0,873		0,105	0,091	0,016	0,168
7	1,011	1,269	1,346	1,309		0,804	1,123	1,108	1,012		0,207	0,146	0,238	0,297
8	0,920	1,045	1,241	1,318		0,859	0,982	1,109	1,212		0,061	0,063	0,132	0,106
9	0,709	0,886	1,290	1,362		0,627	0,771	1,218	1,360		0,082	0,115	0,072	0,002
10	0,963	1,164	1,309	1,357		0,802	1,029	1,152	1,173		0,161	0,135	0,157	0,184
11	1,350	1,692	1,546	1,222		1,246	1,561	1,415	1,100		0,104	0,131	0,131	0,122
12	0,821	1,059	1,182	1,296		0,813	1,048	1,090	1,151		0,008	0,011	0,092	0,145
13	1,340	1,525	1,574	1,465		1,029	1,276	1,334	1,400		0,311	0,249	0,240	0,065
14	1,153	1,212	1,478	1,721		1,124	1,195	1,291	1,414		0,029	0,017	0,187	0,307
15	0,664	0,795	0,879	1,094		0,502	0,664	0,859	0,905		0,162	0,131	0,020	0,189

	TFA - Mesiobuccal Canal													
	Apical – Mesial Side					Apical – Mesial Side					Apical – Mesial Side			
	Anatomical Dentin Thickness (X1)					Remaining Dentin Thickness (X2)					Dentin Removed (X1-X2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	0,952	1,085	1,321	1,510		0,939	1,090	1,189	1,230		0,013	0,005	0,132	0,280
2	0,846	1,296	1,608	1,810		0,796	1,010	1,364	1,591		0,050	0,286	0,244	0,219
3	1,892	1,756	1,880	1,763		1,680	1,661	1,768	1,630		0,212	0,095	0,112	0,133
4	0,823	1,059	1,323	1,319		0,807	1,005	1,125	1,305		0,016	0,054	0,198	0,014
5	1,057	1,161	1,290	1,416		0,912	1,052	1,158	1,332		0,145	0,109	0,132	0,084
6	0,787	0,902	1,082	1,048		0,771	0,885	1,041	1,034		0,016	0,017	0,041	0,014
7	2,131	2,051	2,080	2,069		1,983	2,028	1,990	1,916		0,148	0,023	0,090	0,153
8	1,283	1,123	1,154	1,241		1,071	0,978	0,946	1,094		0,212	0,145	0,208	0,147
9	0,817	0,739	0,919	1,029		0,780	0,669	0,757	0,961		0,037	0,070	0,162	0,068
10	1,276	1,361	1,356	1,487		1,058	1,087	1,237	1,302		0,218	0,274	0,119	0,185
11	1,238	1,321	1,319	1,543		1,071	1,203	1,206	1,344		0,167	0,118	0,113	0,199
12	1,746	1,653	1,888	1,928		1,705	1,632	1,738	1,696		0,041	0,021	0,150	0,232
13	1,059	1,108	1,031	1,112		0,920	0,962	0,913	0,959		0,139	0,146	0,118	0,153
14	1,230	1,402	1,366	1,536		1,191	1,362	1,255	1,378		0,039	0,040	0,111	0,158
15	1,161	1,215	1,420	1,539		1,084	1,074	1,299	1,423		0,077	0,141	0,121	0,116

	TFA- Mesiobuccal Canal													
	Apical – Distal Side					Apical – Distal Side					Apical – Distal Side			
	Anatomical Dentin Thickness (Y1)					Remaining Dentin Thickness (Y2)					Dentin Removed (Y1-Y2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	0,979	1,330	1,571	1,744		0,839	1,233	1,507	1,548		0,140	0,097	0,064	0,196
2	1,391	1,587	1,626	1,668		1,272	1,550	1,548	1,533		0,119	0,037	0,078	0,135
3	2,032	2,230	2,069	2,340		2,008	2,180	2,054	2,194		0,024	0,050	0,015	0,146
4	0,768	0,796	0,846	1,011		0,656	0,687	0,767	0,807		0,112	0,109	0,079	0,204
5	1,156	1,447	1,308	1,163		1,145	1,371	1,225	1,085		0,011	0,076	0,083	0,078
6	0,656	1,046	1,006	1,052		0,634	0,899	0,920	0,912		0,022	0,147	0,086	0,140
7	1,443	1,869	2,088	2,299		1,328	1,760	1,994	2,173		0,115	0,109	0,094	0,126
8	0,851	1,129	1,220	1,026		0,730	0,997	1,068	0,944		0,121	0,132	0,152	0,082
9	1,123	1,215	0,982	0,859		0,984	1,076	0,901	0,583		0,139	0,139	0,081	0,276
10	1,058	1,296	1,454	1,308		1,004	1,090	1,191	1,173		0,054	0,206	0,263	0,135
11	0,886	1,272	1,295	1,371		0,822	1,151	1,303	1,247		0,064	0,121	-0,008	0,124
12	0,225	0,887	1,206	1,205		0,213	0,798	1,149	1,154		0,012	0,089	0,057	0,051
13	0,780	1,006	1,238	1,343		0,712	0,920	1,128	1,193		0,068	0,086	0,110	0,150
14	1,309	1,348	1,003	1,006		1,297	1,242	0,959	0,940		0,012	0,106	0,044	0,066
15	1,460	1,636	1,521	1,400		1,273	1,384	1,420	1,302		0,187	0,252	0,101	0,098

	Reciproc - Mesiobuccal Canal													
	Coronal – Mesial Side					Coronal – Mesial Side					Coronal – Mesial Side			
	Anatomical Dentin Thickness (X1)					Remaining Dentin Thickness (X2)					Dentin Removed (X1-X2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	0,954	1,096	1,240	1,303		0,810	0,985	1,284	1,363		0,144	0,111	0,044	0,060
2	1,496	1,593	1,592	1,665		1,377	1,470	1,476	1,586		0,119	0,123	0,116	0,079
3	1,588	1,604	1,583	1,464		1,497	1,533	1,532	1,423		0,091	0,071	0,051	0,041
4	0,973	0,995	1,195	1,465		0,760	0,670	0,708	1,007		0,213	0,325	0,487	0,458
5	1,633	1,535	1,634	1,796		1,527	1,503	1,525	1,571		0,106	0,032	0,109	0,225
6	1,751	1,604	1,491	1,557		1,730	1,530	1,448	1,320		0,021	0,074	0,043	0,237
7	1,755	1,718	1,580	1,639		1,650	1,564	1,369	1,227		0,105	0,154	0,211	0,412
8	1,529	1,816	1,968	1,701		1,322	1,805	1,672	1,503		0,207	0,011	0,296	0,198
9	1,312	1,334	1,371	1,658		0,987	1,084	1,449	1,502		0,325	0,250	0,078	0,156
10	1,166	1,083	1,095	1,245		1,176	0,908	1,241	1,138		0,010	0,175	0,146	0,107
11	1,244	1,325	1,360	1,452		1,167	1,130	1,255	1,375		0,077	0,195	0,105	0,077
12	1,164	1,164	1,321	1,313		1,096	1,045	1,234	1,278		0,068	0,119	0,087	0,035
13	0,976	1,241	1,241	1,688		0,887	0,946	1,023	1,567		0,089	0,295	0,218	0,121
14	1,390	1,182	1,300	1,448		1,095	0,857	1,035	1,300		0,295	0,325	0,265	0,148
15	1,302	1,330	1,303	1,615		1,064	1,093	1,006	1,038		0,238	0,237	0,297	0,577

	Reciproc- Mesiobuccal Canal												
	Coronal – Distal Side					Coronal – Distal Side					Coronal – Distal Side		
	Anatomical Dentin Thickness (Y1)					Remaining Dentin Thickness (Y2)					Dentin Removed (Y1-Y2)		
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	1,319	1,493	1,223	1,510		1,019	1,106	0,989	0,889		0,300	0,387	0,234	0,621
2	1,570	1,554	1,669	2,250		1,149	0,951	0,973	1,209		0,421	0,603	0,696	1,041
3	1,517	1,537	1,682	1,719		1,312	1,314	1,229	1,161		0,205	0,223	0,453	0,558
4	1,077	1,193	1,135	1,088		0,760	0,670	0,708	1,007		0,317	0,523	0,427	0,081
5	1,437	1,502	1,372	1,339		1,122	0,937	0,893	1,025		0,315	0,565	0,479	0,314
6	1,949	1,956	1,816	1,767		1,864	1,803	1,418	1,225		0,085	0,153	0,398	0,542
7	2,164	1,877	1,753	1,530		1,962	1,621	1,674	1,188		0,202	0,256	0,079	0,342
8	2,754	3,659	1,536	1,576		2,656	3,349	1,306	1,160		0,098	0,310	0,230	0,416
9	1,438	1,472	1,574	1,866		1,404	1,244	0,994	1,267		0,034	0,228	0,580	0,599
10	1,620	1,190	0,963	1,023		1,448	0,959	0,688	0,741		0,172	0,231	0,275	0,282
11	1,057	1,286	1,486	1,338		0,900	0,766	0,826	0,813		0,157	0,520	0,660	0,525
12	1,270	1,406	1,530	1,998		1,172	1,083	1,208	1,889		0,098	0,323	0,322	0,109
13	0,976	1,241	1,241	1,688		0,887	0,946	1,023	1,567		0,089	0,295	0,218	0,121
14	1,015	1,152	1,152	1,182		0,710	0,798	0,827	0,680		0,305	0,354	0,325	0,502
15	1,302	1,330	1,303	1,615		1,064	1,093	1,006	1,038		0,238	0,237	0,297	0,577

	Hyflex CM - Mesiobuccal Canal												
	Coronal – Mesial Side					Coronal – Mesial Side					Coronal – Mesial Side		
	Anatomical Dentin Thickness (X1)					Remaining Dentin Thickness (X2)					Dentin Removed (X1-X2)		
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	1,516	1,484	1,472	1,472		1,234	0,988	1,075	1,153		0,282	0,496	0,397	0,319
2	1,359	1,369	1,596	1,626		1,094	1,212	1,448	1,537		0,265	0,157	0,148	0,089
3	1,212	1,292	1,400	1,536		1,065	1,162	1,279	1,469		0,147	0,130	0,121	0,067
4	1,579	1,732	1,693	1,641		1,252	1,471	1,574	1,551		0,327	0,261	0,119	0,090
5	1,843	1,951	1,712	1,586		1,690	1,665	1,551	1,454		0,153	0,286	0,161	0,132
6	1,041	1,181	1,115	1,402		0,873	0,639	0,396	0,533		0,168	0,542	0,719	0,869
7	1,020	1,213	1,375	1,514		0,690	1,103	1,254	1,469		0,330	0,110	0,121	0,045
8	1,094	1,237	1,380	1,566		0,836	1,004	1,287	1,467		0,258	0,233	0,093	0,099
9	1,215	1,360	1,359	1,480		1,005	1,093	1,241	1,479		0,210	0,267	0,118	0,001
10	1,184	1,181	1,295	1,543		0,927	0,921	1,088	1,373		0,257	0,260	0,207	0,170
11	1,627	1,444	1,375	1,536		1,312	1,296	1,229	1,339		0,315	0,148	0,146	0,197
12	1,495	1,576	1,632	1,721		1,164	1,389	1,443	1,623		0,331	0,187	0,189	0,098
13	1,574	1,721	1,661	1,744		1,382	1,590	1,578	1,700		0,192	0,131	0,083	0,044
14	1,125	1,240	1,362	1,510		0,900	1,226	1,338	1,467		0,225	0,014	0,024	0,043
15	1,203	1,247	1,247	1,408		0,902	0,952	1,140	1,074		0,301	0,295	0,107	0,334

	Hyflex CM- Mesiobuccal Canal													
	Coronal – Distal Side					Coronal – Distal Side					Coronal – Distal Side			
	Anatomical Dentin Thickness (Y1)					Remaining Dentin Thickness (Y2)					Dentin Removed (Y1-Y2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	1,216	1,569	1,42	1,573		1,137	1,438	1,251	1,351		0,079	0,131	0,169	0,222
2	1,158	1,032	1,169	1,3		0,796	0,715	0,788	0,803		0,362	0,317	0,381	0,497
3	1,335	1,247	1,333	1,292		1,195	1,119	0,916	0,813		0,140	0,128	0,417	0,479
4	1,374	1,481	1,472	1,508		1,284	1,248	1,052	0,993		0,090	0,233	0,420	0,515
5	1,771	1,765	1,855	1,855		1,660	1,710	1,642	1,523		0,111	0,055	0,213	0,332
6	1,243	1,215	1,429	1,454		0,900	0,978	1,269	1,348		0,343	0,237	0,160	0,106
7	1,309	1,212	1,356	1,346		1,012	0,800	0,623	0,824		0,297	0,412	0,733	0,522
8	1,241	1,318	1,527	1,746		1,109	1,212	1,129	1,112		0,132	0,106	0,398	0,634
9	1,33	1,241	1,421	1,375		1,093	0,680	1,190	0,798		0,237	0,561	0,231	0,577
10	1,357	1,412	1,551	1,856		1,173	1,196	1,208	1,431		0,184	0,216	0,343	0,425
11	1,546	1,222	1,238	1,309		1,415	1,100	0,968	0,873		0,131	0,122	0,270	0,436
12	1,182	1,296	1,444	1,26		1,090	1,151	0,923	0,739		0,092	0,145	0,521	0,521
13	1,463	1,317	1,36	1,382		0,905	0,715	0,361	0,502		0,558	0,602	0,999	0,880
14	1,721	1,686	1,544	1,521		1,414	1,384	1,103	1,154		0,307	0,302	0,441	0,367
15	1,213	1,353	1,215	1,414		0,943	1,074	0,787	1,000		0,270	0,279	0,428	0,414

	TFA - Mesiobuccal Canal													
	Coronal – Mesial Side					Coronal – Mesial Side					Coronal – Mesial Side			
	Anatomical Dentin Thickness (X1)					Remaining Dentin Thickness (X2)					Dentin Removed (X1-X2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	1,400	1,087	1,241	1,380		1,241	1,074	1,191	1,360		0,159	0,013	0,050	0,020
2	1,925	1,886	1,455	1,708		1,795	1,804	1,411	1,536		0,130	0,082	0,044	0,172
3	1,880	1,763	1,714	1,821		1,768	1,630	1,690	1,757		0,112	0,133	0,024	0,064
4	1,282	1,443	1,206	1,269		1,224	1,103	1,061	1,125		0,058	0,340	0,145	0,144
5	1,416	1,560	1,559	1,591		1,332	1,415	1,459	1,544		0,084	0,145	0,100	0,047
6	1,029	1,029	1,156	1,375		0,946	0,840	1,005	1,335		0,083	0,189	0,151	0,040
7	2,069	1,908	2,053	1,803		1,916	1,800	1,982	1,632		0,153	0,108	0,071	0,171
8	1,300	1,392	1,512	1,688		1,183	1,272	1,392	1,507		0,117	0,120	0,120	0,181
9	1,029	1,254	1,338	1,388		0,961	1,071	1,230	1,475		0,068	0,183	0,108	0,087
10	1,356	1,487	1,472	1,657		1,237	1,302	1,360	1,463		0,119	0,185	0,112	0,194
11	1,543	1,401	1,566	1,602		1,344	1,242	1,389	1,532		0,199	0,159	0,177	0,070
12	1,401	1,544	1,182	1,300		1,192	1,426	1,005	1,124		0,209	0,118	0,177	0,176
13	1,112	1,213	1,295	1,242		0,959	1,006	1,071	1,233		0,153	0,207	0,224	0,009
14	1,366	1,536	1,509	1,599		1,255	1,378	1,323	1,460		0,111	0,158	0,186	0,139
15	1,429	1,629	1,625	1,717		1,367	1,514	1,597	1,684		0,062	0,115	0,028	0,033

	TFA- Mesiobuccal Canal														
	Coronal– Distal Side					Coronal– Distal Side					Coronal– Distal Side			
	Anatomical Dentin Thickness (Y1)					Remaining Dentin Thickness (Y2)					Dentin Removed (Y1-Y2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	1,571	1,295	1,233	1,382		1,318	1,090	0,969	1,024		0,253	0,205	0,264	0,358
2	1,454	1,639	1,888	1,625		1,509	1,223	1,620	1,485		0,055	0,416	0,268	0,140
3	2,069	2,340	1,879	2,196		2,054	2,194	1,523	2,065		0,015	0,146	0,356	0,131
4	0,834	0,982	0,836	0,863		0,796	0,648	0,463	0,545		0,038	0,334	0,373	0,318
5	1,163	0,988	1,272	0,934		1,085	0,960	0,963	0,766		0,078	0,028	0,309	0,168
6	1,082	0,939	1,087	1,375		0,939	0,925	0,648	0,788		0,143	0,014	0,439	0,587
7	2,299	2,385	2,317	1,839		2,173	2,299	2,133	1,770		0,126	0,086	0,184	0,069
8	1,036	1,212	1,258	1,335		0,712	0,753	0,645	0,934		0,324	0,459	0,613	0,401
9	0,859	0,715	0,674	0,927		0,583	0,516	0,495	0,582		0,276	0,199	0,179	0,345
10	1,454	1,308	1,510	1,590		1,191	1,173	1,279	1,200		0,263	0,135	0,231	0,390
11	1,371	1,309	1,451	1,866		1,247	1,235	1,024	1,164		0,124	0,074	0,427	0,702
12	1,234	1,360	1,565	1,890		1,129	0,976	0,979	1,439		0,105	0,384	0,586	0,451
13	1,343	1,477	1,548	1,672		1,193	1,360	1,306	1,257		0,150	0,117	0,242	0,415
14	1,003	1,006	1,317	1,608		0,959	0,940	1,141	1,206		0,044	0,066	0,176	0,402
15	1,426	1,544	1,598	2,134		1,371	1,449	1,183	1,951		0,055	0,095	0,415	0,183

	Shaping Time (s) – Mesiobuccal Canal		
	Reciproc	Hyflex CM	TFA
Specimen/level			
1	94	42	9
2	115	119	19
3	89	40	35
4	152	83	26
5	69	91	9
6	63	52	11
7	56	96	10
8	79	44	9
9	64	100	16
10	79	50	24
11	73	75	96
12	68	78	104
13	56	127	116
14	56	68	114
15	60	69	73

The absolute values recorded of the evaluation of the distobuccal canals of maxillary molars prepared with three heat-treated NiTi Alloys

	Transportation – Distobuccal Canal - Reciproc								
	Apical Transportation					Coronal Transportation			
Specimen/ Level	1	2	3	4		4	3	2	1
1	0,063	0,264	0,027	-0,340		-0,020	-0,390	-0,390	-0,400
2	0,381	0,120	-0,159	0,019		0,270	-0,130	-0,229	-0,179
3	0,035	0,069	0,165	0,158		0,158	-0,082	-0,441	-0,359
4	-0,086	0,036	-0,106	-0,251		-0,106	-0,251	-0,191	-0,110
5	-0,018	-0,024	0,079	-0,323		0,079	-0,323	-0,634	-0,187
6	0,180	0,245	0,108	0,068		0,035	0,027	-0,051	0,048
7	-0,146	0,311	0,327	-0,098		0,327	-0,098	-0,262	-0,470
8	0,041	0,006	0,110	0,003		0,110	0,003	-0,090	-0,224
9	-0,019	0,005	0,054	0,010		0,010	-0,102	-0,336	-0,202
10	0,129	-0,067	-0,168	-0,182		-0,168	-0,182	-0,482	-0,615
11	0,595	-0,004	0,224	0,066		-0,092	-0,278	-0,362	-0,439
12	0,063	0,143	0,083	-0,180		-0,228	-0,247	-0,279	-0,085
13	0,383	0,181	0,133	-0,233		0,181	0,133	-0,233	-0,460
14	0,090	0,148	0,123	-0,019		-0,019	-0,148	-0,177	-0,245
15	0,054	0,094	-0,121	0,019		0,132	-0,094	-0,014	-0,038

	Transportation – Distobuccal Canal – Hyflex CM								
	Apical Transportation					Coronal Transportation			
Specimen/ Level	1	2	3	4		4	3	2	1
1	-0,062	-0,015	0,127	0,229		-0,015	0,127	0,229	-0,266
2	0,089	0,239	-0,016	0,055		-0,057	-0,442	-0,278	-0,354
3	-0,063	0,059	-0,029	0,025		-0,029	0,025	-0,258	-0,082
4	0,054	0,034	0,102	-0,101		-0,051	-0,485	-0,615	-0,554
5	0,044	-0,031	0,145	0,224		0,108	0,193	-0,463	-0,311
6	-0,139	0,084	0,204	-0,019		-0,019	-0,218	-0,458	-0,459
7	0,078	-0,028	0,064	0,049		0,049	-0,140	-0,242	-0,077
8	0,145	-0,026	0,070	0,076		0,070	0,076	-0,071	-0,202
9	-0,039	0,013	0,028	0,030		0,028	0,030	0,375	0,434
10	-0,004	0,103	-0,011	0,101		0,101	0,221	0,112	-0,295
11	-0,055	-0,188	-0,021	0,077		-0,021	0,077	-0,072	-0,168
12	0,007	0,070	-0,098	-0,057		-0,098	-0,057	-0,163	-0,439
13	0,084	0,082	0,084	0,111		0,146	-0,131	-0,324	-0,585
14	0,157	0,223	0,221	-0,117		0,221	-0,117	-0,512	-0,593
15	-0,069	0,049	-0,045	-0,053		0,009	0,065	0,061	0,014

	Transportation – Distobuccal Canal - TFA								
	Apical Transportation					Coronal Transportation			
Specimen/ Level	1	2	3	4		4	3	2	1
1	-0,052	0,001	-0,009	0,119		-0,017	0,029	-0,219	-0,095
2	0,134	-0,054	0,183	0,138		0,183	0,138	-0,200	-0,062
3	0,092	0,078	0,091	0,054		0,091	0,054	0,174	-0,027
4	-0,008	0,164	0,009	0,000		-0,148	-0,024	-0,169	-0,240
5	0,007	0,066	0,019	0,108		0,108	0,241	-0,285	-0,085
6	-0,009	0,011	-0,038	0,064		0,016	-0,072	-0,057	-0,179
7	-0,166	0,073	-0,015	-0,205		-0,205	0,021	-0,048	0,074
8	-0,061	-0,082	0,138	0,088		0,088	-0,219	-0,146	-0,165
9	-0,026	-0,042	-0,006	0,080		0,080	0,005	-0,123	-0,028
10	-0,103	-0,260	-0,054	0,083		-0,054	0,083	-0,060	0,179
11	-0,090	-0,023	-0,064	-0,447		-0,064	-0,447	-0,264	-0,008
12	-0,024	0,004	0,062	-0,143		-0,127	-0,108	-0,041	-0,049
13	-0,021	0,006	-0,063	0,029		0,029	0,160	-0,037	-0,107
14	-0,080	-0,072	-0,043	-0,019		-0,072	-0,043	-0,019	-0,074
15	0,090	0,086	0,059	0,078		0,059	0,078	-0,164	-0,038

	Centering Ability – Distobuccal Canal - Reciproc								
	Apical Third					Coronal Third			
Specimen/ Level	1	2	3	4		4	3	2	1
1	0,471	0,140	0,784	0,117		0,816	0,039	0,093	-0,142
2	0,214	0,656	0,579	0,941		0,025	0,319	0,302	0,073
3	0,729	0,716	0,443	0,413		0,413	0,552	0,052	0,233
4	0,211	0,390	0,418	0,067		0,418	0,067	0,021	0,453
5	0,100	0,684	0,674	0,139		0,674	0,139	0,068	0,448
6	0,241	0,306	0,473	0,632		0,827	0,898	0,802	0,865
7	0,277	0,404	-0,022	0,616		-0,022	0,616	0,121	0,159
8	0,739	0,967	0,247	0,983		0,247	0,983	0,695	0,275
9	0,910	0,911	0,550	0,919		0,919	0,386	-0,063	0,273
10	0,275	0,690	0,368	0,536		0,368	0,536	0,148	0,011
11	0,196	0,960	0,128	0,154		0,343	0,100	0,170	0,210
12	0,492	0,373	0,539	0,323		0,203	0,223	0,054	0,682
13	0,133	0,492	0,549	0,336		0,492	0,549	0,336	0,222
14	0,565	0,500	0,490	0,862		0,862	0,285	0,335	0,194
15	0,530	0,561	0,447	0,881		0,397	0,742	0,955	0,895

	Centering Ability – Distobuccal Canal – Hyflex CM								
	Apical Third					Coronal Third			
Specimen/ Level	1	2	3	4		4	3	2	1
1	0,674	0,919	0,596	0,278		0,919	0,596	0,278	0,265
2	0,500	0,195	0,910	0,623		0,725	0,002	0,150	0,063
3	0,330	0,508	0,803	0,706		0,803	0,706	0,104	0,000
4	0,774	0,823	0,649	0,633		0,870	0,353	0,259	0,301
5	0,740	0,696	0,478	0,293		0,601	0,543	0,041	0,134
6	0,232	0,596	0,224	0,896		0,535	0,080	0,183	0,183
7	0,377	0,736	0,630	0,839		0,839	0,607	0,411	0,736
8	0,116	0,350	0,157	-0,434		0,157	-0,434	0,101	0,024
9	0,409	0,833	0,699	0,577		0,699	0,577	0,046	0,129
10	0,862	0,646	0,943	0,596		0,596	0,338	0,627	0,433
11	0,722	0,288	0,865	0,483		0,865	0,483	0,679	0,501
12	0,938	0,466	0,269	0,467		0,269	0,467	0,432	0,007
13	0,592	0,481	0,576	0,695		0,604	0,725	0,417	0,278
14	0,349	0,276	0,303	0,562		0,303	0,562	-0,049	0,003
15	0,477	0,664	0,847	0,660		0,894	0,316	0,637	0,922

	Centering Ability – DistoBuccal Canal - TFA								
	Apical Third					Coronal Third			
Specimen/ Level	1	2	3	4		4	3	2	1
1	0,480	0,989	0,839	0,462		0,770	0,777	0,134	0,527
2	0,056	0,677	0,247	0,061		0,247	0,061	0,327	0,790
3	0,425	0,345	0,438	0,708		0,438	0,708	0,372	0,828
4	0,840	0,052	0,816	1,000		0,135	0,707	0,006	0,259
5	0,904	0,704	0,887	0,255		0,255	0,581	0,021	0,472
6	0,903	0,866	0,387	0,423		0,500	0,579	0,763	0,415
7	0,126	0,475	0,906	0,235		0,235	0,777	0,716	0,513
8	0,772	0,526	0,324	0,254		0,254	-0,023	0,381	0,214
9	0,770	0,344	0,925	0,192		0,192	0,926	0,128	0,748
10	0,428	0,116	0,738	0,407		0,738	0,407	0,793	0,374
11	0,480	0,610	0,340	0,206		0,340	0,206	0,080	0,961
12	0,631	0,966	0,139	0,255		0,324	0,397	0,750	0,686
13	0,588	0,850	0,707	0,275		0,275	0,352	0,815	0,609
14	0,403	0,111	0,594	0,804		0,111	0,594	0,804	0,345
15	0,280	0,456	0,330	0,544		0,330	0,544	0,234	0,831

	Reciproc – Distobuccal Canal								
	Apical Volume(mm^3)					Entire Volume (mm^3)			
Specimen/analysis	Initial Volume (mm^3)	Final Volume (mm^3)	Removed Volume (mm^3)	Percentage of increased volume (mm^3)		Initial Volume (mm^3)	Final Volume (mm^3)	Removed Volume (mm^3)	Percentage of increased volume (mm^3)
1	0,239	0,987	0,748	312,971		0,583	2,027	1,444	247,684
2	0,064	0,701	0,637	995,313		0,984	2,845	1,861	189,126
3	0,122	0,795	0,673	551,639		0,351	2,578	2,227	634,473
4	0,486	0,959	0,473	97,325		0,486	1,002	0,516	106,173
5	0,747	1,163	0,416	55,689		1,367	2,478	1,111	81,273
6	0,159	0,444	0,285	179,245		0,721	2,671	1,950	270,458
7	0,139	0,884	0,745	535,971		0,503	2,075	1,572	312,525
8	0,076	0,547	0,471	619,737		0,183	1,179	0,996	544,262
9	0,351	0,687	0,336	95,726		1,557	2,438	0,881	56,583
10	0,234	0,833	0,599	255,983		0,319	1,941	1,622	508,464
11	0,726	0,952	0,226	31,129		2,434	3,655	1,221	50,164
12	0,485	0,790	0,305	62,887		1,986	3,010	1,024	51,561
13	0,086	0,984	0,898	1.044,302		0,170	1,659	1,489	875,882
14	0,088	0,555	0,467	530,682		0,608	1,702	1,094	179,934
15	0,483	0,521	0,038	7,867		2,407	2,928	0,521	21,645

	Hyflex CM – Distobuccal Canal								
	Apical Volume(mm^3)					Entire Volume (mm^3)			
Specimen/analysis	Initial Volume (mm^3)	Final Volume (mm^3)	Removed Volume (mm^3)	Percentage of increased volume (mm^3)		Initial Volume (mm^3)	Final Volume (mm^3)	Removed Volume (mm^3)	Percentage of increased volume (mm^3)
1	0,460	0,956	0,496	107,826		0,700	1,619	0,919	131,286
2	0,408	0,912	0,504	123,529		1,698	3,902	2,204	129,800
3	0,177	0,388	0,211	119,209		0,462	1,147	0,685	148,268
4	0,116	0,737	0,621	535,345		0,686	3,838	3,152	459,475
5	0,044	0,450	0,406	922,727		1,117	2,757	1,640	146,822
6	0,124	0,671	0,547	441,129		0,471	2,238	1,767	375,159
7	0,216	0,502	0,286	132,407		0,743	1,864	1,121	150,875
8	0,201	0,222	0,021	10,448		0,801	0,841	0,040	4,994
9	1,320	1,671	0,351	26,591		2,367	3,585	1,218	51,458
10	0,099	0,400	0,301	304,040		0,442	1,587	1,145	259,050
11	0,299	0,660	0,361	120,736		0,830	1,690	0,860	103,614
12	0,273	0,973	0,700	256,410		0,667	2,185	1,518	227,586
13	0,151	0,379	0,228	150,993		0,734	2,749	2,015	274,523
14	0,203	0,911	0,708	348,768		0,611	2,234	1,623	265,630
15	0,255	0,550	0,295	115,686		1,764	2,365	0,601	34,070

	TFA –Distobuccal Canal								
	Apical Volume(mm³)					Whole Volume (mm³)			
Specimen/level	Initial Volume (mm³)	Final Volume (mm³)	Removed Volume (mm³)	Percentage of increased volume (mm³)		Initial Volume (mm³)	Final Volume (mm³)	Removed Volume (mm³)	Percentage of increased volume (mm³)
1	0,508	0,541	0,033	6,496		4,664	4,776	0,112	2,401
2	0,233	0,436	0,203	87,124		0,732	1,234	0,502	68,579
3	0,166	0,471	0,305	183,735		0,380	0,813	0,433	113,947
4	0,092	0,198	0,106	115,217		1,147	1,867	0,720	62,772
5	0,664	0,852	0,188	28,313		2,015	2,874	0,859	42,630
6	0,227	0,334	0,107	47,137		1,909	2,389	0,480	25,144
7	0,143	0,166	0,023	16,084		0,599	0,729	0,130	21,703
8	0,307	0,413	0,106	34,528		1,204	1,748	0,544	45,183
9	0,141	0,170	0,029	20,567		0,669	0,968	0,299	44,694
10	0,203	0,486	0,283	139,409		0,510	1,334	0,824	161,569
11	0,215	0,384	0,169	78,605		0,466	0,997	0,531	113,948
12	0,207	0,344	0,137	66,184		1,810	2,621	0,811	44,807
13	0,006	0,092	0,086	1433,333		0,134	0,434	0,300	223,881
14	0,268	0,281	0,013	4,851		0,465	0,497	0,032	6,882
15	0,438	0,456	0,018	4,110		1,043	1,140	0,097	9,300

	Reciproc - Distobuccal Canal													
	Apical – Mesial Side					Apical – Mesial Side					Apical – Mesial Side			
	Anatomical Dentin Thickness (X1)					Remaining Dentin Thickness (X2)					Dentin Removed (X1-X2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	0,717	0,862	0,933	1,095		0,661	0,819	0,835	0,711		0,056	0,043	0,098	0,384
2	1,091	1,385	1,688	1,560		0,987	1,156	1,310	1,255		0,104	0,229	0,378	0,305
3	1,015	1,236	1,415	1,460		0,921	1,062	1,284	1,349		0,094	0,174	0,131	0,111
4	0,671	0,877	0,913	1,034		0,562	0,854	0,731	0,765		0,109	0,023	0,182	0,269
5	1,340	1,298	1,187	1,273		1,320	1,222	1,024	0,898		0,020	0,076	0,163	0,375
6	1,105	1,324	1,410	1,493		1,048	1,216	1,313	1,376		0,057	0,108	0,097	0,117
7	1,856	1,789	1,417	1,619		1,654	1,578	1,424	1,364		0,202	0,211	0,007	0,255
8	2,026	2,764	3,670	4,536		1,910	2,586	3,634	4,361		0,116	0,178	0,036	0,175
9	1,532	1,392	1,421	1,439		1,320	1,341	1,355	1,326		0,212	0,051	0,066	0,113
10	0,686	0,776	1,021	1,033		0,637	0,560	0,755	0,641		0,049	0,216	0,266	0,392
11	0,972	1,149	1,226	1,073		0,827	1,050	1,193	1,061		0,145	0,099	0,033	0,012
12	0,712	1,038	0,962	0,997		0,651	0,953	0,865	0,731		0,061	0,085	0,097	0,266
13	1,508	1,862	2,013	2,351		1,449	1,687	1,851	2,000		0,059	0,175	0,162	0,351
14	1,271	1,333	1,335	1,095		1,154	1,185	1,217	0,957		0,117	0,148	0,118	0,138
15	0,888	0,918	1,055	1,112		0,827	0,798	0,836	0,972		0,061	0,120	0,219	0,140

	Reciproc- Distobuccal Canal													
	Apical – Distal Side					Apical – Distal Side					Apical – Distal Side			
	Anatomical Dentin Thickness (Y1)					Remaining Dentin Thickness (Y2)					Dentin Removed (Y1-Y2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	0,901	1,322	1,421	1,407		0,782	1,015	1,296	1,362		0,119	0,307	0,125	0,045
2	2,362	2,241	1,952	1,980		1,877	1,892	1,733	1,656		0,485	0,349	0,219	0,324
3	1,148	1,261	1,236	1,159		1,019	1,018	0,940	0,890		0,129	0,243	0,296	0,269
4	0,841	1,020	1,075	1,124		0,818	0,961	0,999	1,106		0,023	0,059	0,076	0,018
5	2,141	1,549	1,547	1,426		2,139	1,497	1,305	1,374		0,002	0,052	0,242	0,052
6	1,088	1,448	1,577	1,623		0,851	1,095	1,372	1,438		0,237	0,353	0,205	0,185
7	0,965	1,757	1,789	1,593		0,909	1,235	1,469	1,436		0,056	0,522	0,320	0,157
8	0,814	1,126	1,174	1,263		0,657	0,942	1,028	1,085		0,157	0,184	0,146	0,178
9	0,982	1,229	1,339	1,348		0,789	1,173	1,219	1,225		0,193	0,056	0,120	0,123
10	0,998	1,004	1,154	1,225		0,820	0,855	1,056	1,015		0,178	0,149	0,098	0,210
11	1,608	1,186	1,311	1,291		0,868	1,091	1,054	1,213		0,740	0,095	0,257	0,078
12	0,981	1,065	1,009	1,003		0,857	0,837	0,829	0,917		0,124	0,228	0,180	0,086
13	1,152	1,242	1,359	1,448		0,710	0,886	1,064	1,330		0,442	0,356	0,295	0,118
14	1,333	1,537	1,512	1,271		1,126	1,241	1,271	1,152		0,207	0,296	0,241	0,119
15	0,859	1,041	0,939	0,993		0,744	0,827	0,841	0,834		0,115	0,214	0,098	0,159

	Hyflex CM - Distobuccal Canal													
	Apical – Mesial Side					Apical – Mesial Side					Apical – Mesial Side			
	Anatomical Dentin Thickness (X1)					Remaining Dentin Thickness (X2)					Dentin Removed (X1-X2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	1,496	1,716	1,739	1,755		1,615	1,718	1,676	1,745		0,119	0,002	0,063	0,010
2	1,154	1,212	1,213	0,891		1,065	1,154	1,036	0,800		0,089	0,058	0,177	0,091
3	0,953	0,977	1,300	1,242		0,859	0,916	1,153	1,182		0,094	0,061	0,147	0,060
4	1,084	1,097	1,171	1,252		0,899	0,939	0,982	0,977		0,185	0,158	0,189	0,275
5	1,071	1,400	1,543	1,514		0,946	1,298	1,410	1,421		0,125	0,102	0,133	0,093
6	0,902	1,076	1,213	1,313		0,721	0,952	1,154	1,131		0,181	0,124	0,059	0,182
7	0,467	0,697	0,916	0,944		0,420	0,591	0,807	0,689		0,047	0,106	0,109	0,255
8	0,901	0,942	1,171	1,371		0,882	0,902	1,158	1,394		0,019	0,040	0,013	0,023
9	1,111	1,176	1,297	1,336		1,045	1,111	1,232	1,295		0,066	0,065	0,065	0,041
10	0,743	1,003	1,128	0,930		0,714	0,815	0,934	0,781		0,029	0,188	0,194	0,149
11	1,493	1,493	1,344	1,269		1,295	1,229	1,189	1,197		0,198	0,264	0,155	0,072
12	0,598	0,776	1,076	1,213		0,492	0,715	0,942	1,106		0,106	0,061	0,134	0,107
13	0,962	1,330	1,265	1,468		0,840	1,254	1,151	1,215		0,122	0,076	0,114	0,253
14	0,916	1,376	1,682	1,543		0,832	1,291	1,586	1,276		0,084	0,085	0,096	0,267
15	0,991	1,149	1,449	1,421		0,859	1,052	1,154	1,265		0,132	0,097	0,295	0,156

	Hyflex CM- Distobuccal Canal													
	Apical – Distal Side					Apical – Distal Side					Apical – Distal Side			
	Anatomical Dentin Thickness (Y1)					Remaining Dentin Thickness (Y2)					Dentin Removed (Y1-Y2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	1,743	1,889	1,990	2,062		1,615	1,718	1,676	1,745		0,128	0,171	0,314	0,317
2	1,154	1,213	1,108	1,241		0,976	0,916	0,947	1,095		0,178	0,297	0,161	0,146
3	1,124	1,036	1,123	1,182		1,093	0,916	1,005	1,097		0,031	0,120	0,118	0,085
4	1,300	1,421	1,433	1,398		1,061	1,229	1,142	1,224		0,239	0,192	0,291	0,174
5	0,712	0,639	1,011	1,218		0,543	0,568	0,733	0,901		0,169	0,071	0,278	0,317
6	0,545	0,840	1,074	1,106		0,503	0,632	0,811	0,943		0,042	0,208	0,263	0,163
7	0,796	0,727	0,887	1,085		0,671	0,649	0,714	0,781		0,125	0,078	0,173	0,304
8	1,004	1,149	1,463	1,265		0,840	1,135	1,380	1,212		0,164	0,014	0,083	0,053
9	0,928	1,071	1,388	1,164		0,901	0,993	1,295	1,093		0,027	0,078	0,093	0,071
10	0,607	0,942	0,855	0,848		0,582	0,651	0,672	0,598		0,025	0,291	0,183	0,250
11	1,375	1,414	1,455	1,401		1,232	1,338	1,321	1,252		0,143	0,076	0,134	0,149
12	0,847	1,196	1,265	1,363		0,734	1,065	1,229	1,313		0,113	0,131	0,036	0,050
13	1,296	1,177	1,306	1,463		1,090	1,019	1,108	1,099		0,206	0,158	0,198	0,364
14	1,429	1,460	1,414	1,237		1,188	1,152	1,097	1,087		0,241	0,308	0,317	0,150
15	0,878	1,254	1,593	1,632		0,815	1,108	1,343	1,529		0,063	0,146	0,250	0,103

	TFA - Distobuccal Canal													
	Apical – Mesial Side					Apical – Mesial Side					Apical – Mesial Side			
	Anatomical Dentin Thickness (X1)					Remaining Dentin Thickness (X2)					Dentin Removed (X1-X2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	0,923	0,968	1,049	1,336		0,823	0,882	0,993	1,234		0,100	0,086	0,056	0,102
2	1,420	1,582	1,416	1,327		1,412	1,415	1,356	1,318		0,008	0,167	0,060	0,009
3	1,865	2,090	2,175	2,525		1,797	2,049	2,104	2,394		0,068	0,041	0,071	0,131
4	0,667	0,757	0,939	0,993		0,617	0,748	0,899	0,889		0,050	0,009	0,040	0,104
5	1,061	1,197	1,121	0,924		0,995	1,040	0,972	0,887		0,066	0,157	0,149	0,037
6	0,582	0,721	0,857	0,899		0,489	0,650	0,795	0,852		0,093	0,071	0,062	0,047
7	1,750	1,615	1,968	2,361		1,560	1,549	1,809	2,093		0,190	0,066	0,159	0,268
8	1,006	1,123	1,213	1,156		0,739	0,950	1,147	1,126		0,267	0,173	0,066	0,030
9	1,171	1,193	1,151	1,071		1,058	1,129	1,071	1,052		0,113	0,064	0,080	0,019
10	0,877	1,074	1,004	1,298		0,697	0,780	0,798	1,241		0,180	0,294	0,206	0,057
11	1,482	1,774	1,764	1,835		1,309	1,715	1,667	1,272		0,173	0,059	0,097	0,563
12	1,024	1,337	1,429	1,708		0,959	1,223	1,419	1,516		0,065	0,114	0,010	0,192
13	0,740	0,934	1,197	1,125		0,689	0,900	0,982	1,114		0,051	0,034	0,215	0,011
14	1,297	1,247	1,312	1,421		1,163	1,166	1,206	1,324		0,134	0,081	0,106	0,097
15	1,220	1,375	1,584	1,598		1,185	1,303	1,555	1,505		0,035	0,072	0,029	0,093

	TFA- Distobuccal Canal													
	Apical – Distal Side					Apical – Distal Side					Apical – Distal Side			
	Anatomical Dentin Thickness (Y1)					Remaining Dentin Thickness (Y2)					Dentin Removed (Y1-Y2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	0,697	0,988	1,265	1,451		0,649	0,901	1,218	1,23		0,05	0,09	0,05	0,22
2	0,824	1,234	1,589	1,495		0,682	1,121	1,346	1,348		0,14	0,11	0,24	0,15
3	1,254	1,443	1,547	1,63		1,094	1,324	1,385	1,445		0,16	0,12	0,16	0,19
4	0,823	0,954	0,993	1,076		0,781	0,781	0,944	0,972		0,04	0,17	0,05	0,10
5	0,962	1,093	1,149	1,154		0,889	0,87	0,981	1,009		0,07	0,22	0,17	0,15
6	0,901	0,899	0,923	1,034		0,817	0,817	0,899	0,923		0,08	0,08	0,02	0,11
7	1,418	1,652	1,782	1,779		1,394	1,513	1,638	1,716		0,02	0,14	0,14	0,06
8	1,306	1,185	1,213	1,182		1,1	1,094	1,009	1,064		0,21	0,09	0,20	0,12
9	0,817	0,879	0,919	1,004		0,73	0,857	0,845	0,905		0,09	0,02	0,07	0,10
10	1,123	1,23	1,343	1,353		1,046	1,196	1,191	1,213		0,08	0,03	0,15	0,14
11	1,074	1,2	1,353	1,297		0,991	1,164	1,32	1,181		0,08	0,04	0,03	0,12
12	0,923	1,247	1,412	1,468		0,882	1,129	1,34	1,419		0,04	0,12	0,07	0,05
13	0,74	0,836	1,045	1,024		0,71	0,796	0,893	0,984		0,03	0,04	0,15	0,04
14	1,269	1,516	1,465	1,426		1,215	1,507	1,402	1,348		0,05	0,01	0,06	0,08
15	1,258	1,346	1,393	1,555		1,133	1,188	1,305	1,384		0,13	0,16	0,09	0,17

	Reciproc - Distobuccal Canal													
	Coronal – Mesial Side					Coronal – Mesial Side					Coronal – Mesial Side			
	Anatomical Dentin Thickness (X1)					Remaining Dentin Thickness (X2)					Dentin Removed (X1-X2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	1,011	1,124	1,114	1,193		0,875	0,717	0,684	0,847		0,136	0,407	0,430	0,346
2	1,650	2,147	2,385	2,362		1,643	1,956	2,057	2,169		0,007	0,191	0,328	0,193
3	1,460	1,425	1,557	1,561		1,349	1,242	1,092	1,093		0,111	0,183	0,465	0,468
4	0,913	1,034	1,156	1,391		0,731	0,765	0,961	1,190		0,182	0,269	0,195	0,201
5	1,187	1,273	1,603	1,534		1,024	0,898	0,923	1,195		0,163	0,375	0,680	0,339
6	1,601	1,639	1,493	1,615		1,434	1,402	1,236	1,307		0,167	0,237	0,257	0,308
7	1,417	1,619	1,477	1,787		1,424	1,364	1,179	1,228		0,007	0,255	0,298	0,559
8	3,670	4,536	1,280	1,224		3,634	4,361	0,985	0,915		0,036	0,175	0,295	0,309
9	1,439	1,691	1,778	1,902		1,326	1,525	1,462	1,624		0,113	0,166	0,316	0,278
10	1,021	1,033	1,174	1,230		0,755	0,641	0,608	0,608		0,266	0,392	0,566	0,622
11	1,089	1,212	1,307	1,462		0,949	0,903	0,871	0,906		0,140	0,309	0,436	0,556
12	1,068	1,197	1,323	1,885		0,782	0,879	1,028	1,618		0,286	0,318	0,295	0,267
13	1,862	2,013	2,351	2,440		1,687	1,851	2,000	1,849		0,175	0,162	0,351	0,591
14	1,095	1,182	1,212	1,371		0,957	0,975	0,946	1,067		0,138	0,207	0,266	0,304
15	1,049	1,205	1,142	1,166		0,962	0,841	0,832	0,803		0,087	0,364	0,310	0,363

	Reciproc- Distobuccal Canal													
	Coronal – Distal Side					Coronal – Distal Side					Coronal – Distal Side			
	Anatomical Dentin Thickness (Y1)					Remaining Dentin Thickness (Y2)					Dentin Removed (Y1-Y2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	1,421	1,338	1,402	1,508		1,310	1,322	1,362	1,557		0,111	0,016	0,040	0,049
2	1,851	1,531	1,559	1,634		1,574	1,470	1,460	1,620		0,277	0,061	0,099	0,014
3	1,159	1,213	1,338	1,634		0,890	1,112	1,314	1,525		0,269	0,101	0,024	0,109
4	1,075	1,124	1,264	1,345		0,999	1,106	1,260	1,254		0,076	0,018	0,004	0,091
5	1,547	1,426	1,693	1,723		1,305	1,374	1,647	1,571		0,242	0,052	0,046	0,152
6	1,656	1,541	1,498	1,640		1,454	1,277	1,292	1,284		0,202	0,264	0,206	0,356
7	1,789	1,593	1,256	1,287		1,469	1,436	1,220	1,198		0,320	0,157	0,036	0,089
8	1,174	1,263	1,430	1,371		1,028	1,085	1,225	1,286		0,146	0,178	0,205	0,085
9	1,348	1,283	1,181	1,356		1,225	1,219	1,201	1,280		0,123	0,064	0,020	0,076
10	1,154	1,225	1,179	1,273		1,056	1,015	1,095	1,266		0,098	0,210	0,084	0,007
11	1,359	1,403	1,386	1,593		1,311	1,372	1,312	1,476		0,048	0,031	0,074	0,117
12	1,026	1,068	1,246	1,501		0,968	0,997	1,230	1,319		0,058	0,071	0,016	0,182
13	1,242	1,359	1,448	1,609		0,886	1,064	1,330	1,478		0,356	0,295	0,118	0,131
14	1,271	1,359	1,419	1,566		1,152	1,300	1,330	1,507		0,119	0,059	0,089	0,059
15	1,032	1,104	1,229	1,409		0,813	0,834	0,933	1,084		0,219	0,270	0,296	0,325

	Hyflex CM - Distobuccal Canal													
	Coronal – Mesial Side					Coronal – Mesial Side					Coronal – Mesial Side			
	Anatomical Dentin Thickness (X1)					Remaining Dentin Thickness (X2)					Dentin Removed (X1-X2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	1,716	1,739	1,755	2,131		1,530	1,552	1,667	1,769		0,186	0,187	0,088	0,362
2	0,916	1,093	1,303	1,369		0,709	0,650	0,976	0,991		0,207	0,443	0,327	0,378
3	1,300	1,242	1,300	1,641		1,153	1,182	1,012	1,559		0,147	0,060	0,288	0,082
4	1,100	1,318	1,303	1,453		0,709	0,568	0,473	0,661		0,391	0,750	0,830	0,792
5	1,608	1,630	1,612	1,468		1,445	1,401	1,129	1,109		0,163	0,229	0,483	0,359
6	1,313	1,435	1,410	1,623		1,131	0,966	0,912	1,061		0,182	0,469	0,498	0,562
7	0,944	1,071	1,164	1,218		0,689	0,715	0,753	0,926		0,255	0,356	0,411	0,292
8	1,463	1,265	1,317	1,324		1,380	1,212	1,309	1,319		0,083	0,053	0,008	0,005
9	1,297	1,336	1,385	1,478		1,232	1,295	1,367	1,414		0,065	0,041	0,018	0,064
10	0,930	0,946	1,014	1,667		0,781	0,833	0,826	1,147		0,149	0,113	0,188	0,520
11	1,344	1,269	1,361	1,394		1,189	1,197	1,137	1,057		0,155	0,072	0,224	0,337
12	1,076	1,213	1,361	1,324		0,942	1,106	1,074	0,882		0,134	0,107	0,287	0,442
13	1,519	1,444	1,309	1,697		1,296	0,968	0,753	0,887		0,223	0,476	0,556	0,810
14	1,682	1,543	1,456	1,659		1,586	1,276	0,968	1,064		0,096	0,267	0,488	0,595
15	1,442	1,415	1,484	1,568		1,366	1,385	1,377	1,402		0,076	0,030	0,107	0,166

	Hyflex CM- Distobuccal Canal													
	Coronal – Distal Side					Coronal – Distal Side					Coronal – Distal Side			
	Anatomical Dentin Thickness (Y1)					Remaining Dentin Thickness (Y2)					Dentin Removed (Y1-Y2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	1,889	1,990	2,062	1,911		1,718	1,676	1,745	1,815		0,171	0,314	0,317	0,096
2	1,303	1,242	1,478	1,980		1,153	1,241	1,429	1,956		0,150	0,001	0,049	0,024
3	1,123	1,182	1,330	1,655		1,005	1,097	1,300	1,655		0,118	0,085	0,030	0,000
4	1,414	1,441	1,498	1,571		1,074	1,176	1,283	1,333		0,340	0,265	0,215	0,238
5	1,358	1,697	1,380	1,489		1,087	1,275	1,360	1,441		0,271	0,422	0,020	0,048
6	1,106	1,164	1,203	1,350		0,943	0,913	1,163	1,247		0,163	0,251	0,040	0,103
7	1,085	1,181	1,290	1,617		0,781	0,965	1,121	1,402		0,304	0,216	0,169	0,215
8	1,463	1,265	1,317	1,324		1,380	1,212	1,309	1,319		0,083	0,053	0,008	0,005
9	1,388	1,164	1,346	1,728		1,295	1,093	0,953	1,230		0,093	0,071	0,393	0,498
10	0,848	0,858	0,984	1,060		0,598	0,524	0,684	0,835		0,250	0,334	0,300	0,225
11	1,455	1,401	1,480	1,546		1,321	1,252	1,328	1,377		0,134	0,149	0,152	0,169
12	1,265	1,363	1,419	1,378		1,229	1,313	1,295	1,375		0,036	0,050	0,124	0,003
13	1,380	1,457	1,519	1,762		1,011	1,112	1,287	1,537		0,369	0,345	0,232	0,225
14	1,414	1,237	1,206	1,471		1,097	1,087	1,230	1,469		0,317	0,150	0,024	0,002
15	1,632	1,336	1,505	1,475		1,547	1,241	1,337	1,295		0,085	0,095	0,168	0,180

	TFA - Distobuccal Canal													
	Coronal – Mesial Side					Coronal – Mesial Side					Coronal – Mesial Side			
	Anatomical Dentin Thickness (X1)					Remaining Dentin Thickness (X2)					Dentin Removed (X1-X2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	1,400	1,087	1,241	1,380		1,241	1,074	1,191	1,360		0,159	0,013	0,050	0,020
2	1,925	1,886	1,455	1,708		1,795	1,804	1,411	1,536		0,130	0,082	0,044	0,172
3	1,880	1,763	1,714	1,821		1,768	1,630	1,690	1,757		0,112	0,133	0,024	0,064
4	1,282	1,443	1,206	1,269		1,224	1,103	1,061	1,125		0,058	0,340	0,145	0,144
5	1,416	1,560	1,559	1,591		1,332	1,415	1,459	1,544		0,084	0,145	0,100	0,047
6	1,029	1,029	1,156	1,375		0,946	0,840	1,005	1,335		0,083	0,189	0,151	0,040
7	2,069	1,908	2,053	1,803		1,916	1,800	1,982	1,632		0,153	0,108	0,071	0,171
8	1,300	1,392	1,512	1,688		1,183	1,272	1,392	1,507		0,117	0,120	0,120	0,181
9	1,029	1,254	1,338	1,388		0,961	1,071	1,230	1,475		0,068	0,183	0,108	0,087
10	1,356	1,487	1,472	1,657		1,237	1,302	1,360	1,463		0,119	0,185	0,112	0,194
11	1,371	1,309	1,451	1,866		1,247	1,235	1,024	1,164		0,124	0,074	0,427	0,702
12	1,401	1,544	1,182	1,300		1,192	1,426	1,005	1,124		0,209	0,118	0,177	0,176
13	1,112	1,213	1,295	1,242		0,959	1,006	1,071	1,233		0,153	0,207	0,224	0,009
14	1,366	1,536	1,509	1,599		1,255	1,378	1,323	1,460		0,111	0,158	0,186	0,139
15	1,429	1,629	1,625	1,717		1,367	1,514	1,597	1,684		0,062	0,115	0,028	0,033

	TFA- Distobuccal Canal													
	Coronal– Distal Side					Coronal– Distal Side					Coronal– Distal Side			
	Anatomical Dentin Thickness (Y1)					Remaining Dentin Thickness (Y2)					Dentin Removed (Y1-Y2)			
Specimen/level	1	2	3	4		1	2	3	4		1	2	3	4
1	1,571	1,295	1,233	1,382		1,318	1,090	0,969	1,024		0,253	0,205	0,264	0,358
2	1,454	1,639	1,888	1,625		1,509	1,223	1,620	1,485		0,055	0,416	0,268	0,140
3	2,069	2,340	1,879	2,196		2,054	2,194	1,523	2,065		0,015	0,146	0,356	0,131
4	0,834	0,982	0,836	0,863		0,796	0,648	0,463	0,545		0,038	0,334	0,373	0,318
5	1,163	0,988	1,272	0,934		1,085	0,960	0,963	0,766		0,078	0,028	0,309	0,168
6	1,082	0,939	1,087	1,375		0,939	0,925	0,648	0,788		0,143	0,014	0,439	0,587
7	2,299	2,385	2,317	1,839		2,173	2,299	2,133	1,770		0,126	0,086	0,184	0,069
8	1,036	1,212	1,258	1,335		0,712	0,753	0,645	0,934		0,324	0,459	0,613	0,401
9	0,859	0,715	0,674	0,927		0,583	0,516	0,495	0,582		0,276	0,199	0,179	0,345
10	1,454	1,308	1,510	1,590		1,191	1,173	1,279	1,200		0,263	0,135	0,231	0,390
11	1,543	1,401	1,566	1,602		1,344	1,242	1,389	1,532		0,199	0,159	0,177	0,070
12	1,234	1,360	1,565	1,890		1,129	0,976	0,979	1,439		0,105	0,384	0,586	0,451
13	1,343	1,477	1,548	1,672		1,193	1,360	1,306	1,257		0,150	0,117	0,242	0,415
14	1,003	1,006	1,317	1,608		0,959	0,940	1,141	1,206		0,044	0,066	0,176	0,402
15	1,426	1,544	1,598	2,134		1,371	1,449	1,183	1,951		0,055	0,095	0,415	0,183

	Shaping Time (s) – Distobuccal Canal		
	Reciproc	Hyflex CM	TFA
Specimen/level			
1	67	43	52
2	68	137	46
3	68	54	50
4	106	86	78
5	110	94	58
6	78	52	89
7	96	60	71
8	28	37	33
9	91	51	54
10	72	39	80
11	60	92	62
12	54	54	84
13	76	113	110
14	52	46	78
15	55	59	44

APPENDIX E - Table 1 - Statistical evaluation of the canal transportation, centering ability, volume changes, dentin thickness and shaping time for the system evaluated in MB and DB canals of maxillary molars

Mesiobuccal Root –Coronal Dentin Thickness

Mesiobuccal Root –Coronal Dentin Thickness

	Mesial Side														
	1) X1					2) X2					5)X1-X2				
	4	3	2	1		4	3	2	1		4	3	2	1	
REC	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		≅TFA/ ≠HF	n.s	n.s	n.s	
HF	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		≠REC/ ≠TFA	n.s	n.s	n.s	
TFA	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		≠HF/ ≅REC	n.s	n.s	n.s	
P	0,68	1,33	0,66	0,97		0,08	0,43	0,96	0,38		0,00	0,16	0,52	0,28	

	Distal Side													
	3)Y1					4)Y2					6)Y1-Y2			
	4	3	2	1		4	3	2	1		4	3	2	1
REC	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		n.s	≅HF/ ≠TFA	n.s	n.a
HF	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s
TFA	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s
P	0,66	1,90	0,08	0,52		0,92	0,99	0,91	0,43		0,11	0,01	0,70	0,17

* **n.s** No statistical differences were found in the intergroup comparison at the same level (Kruskal-Wallis and Dunn. P>0.05).

Mesiobuccal Root –Apical Dentin Thickness

Mesiobuccal canal –Apical Dentin Thickness

	Mesial Side														
	7) X1					8) X2					11)X1-X2				
	4	3	2	1		4	3	2	1		4	3	2	1	
REC	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		≅ TFA ≠HF	≅TFA ≅ HF	≅TFA ≅ HF	≅TFA ≅ HF	
HF	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		≠TFA ≠REC	≠TFA ≅REC	≠TFA ≅REC	≠TFA ≅REC	
TFA	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		≠HF/ ≅REC	≠HF/ ≅REC	≠HF/ ≅REC	≠HF/ ≅REC	
P	0,24	0,63	0,76	0,87		0,05	0,08	0,62	0,37		0,00	0,00	0,02	0,04	

	Distal Side													
	9)Y1					10)Y2					12)Y1-Y2			
	4	3	2	1		4	3	2	1		4	3	2	1
REC	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		≅ HF/ ≠TFA	n.a	n.a	n.a
HF	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		≅ REC/≅ TFA	n.s	n.s	n.s
TFA	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		≅ HF/ ≠REC	n.s	n.s	n.s
P	0,18	0,56	0,36	0,14		0,96	0,91	0,63	0,19		0,04	0,14	0,18	0,23

Distobuccal Root –Coronal Dentin Thickness

	Distobuccal canal –Coronal Dentin Thickness																												
	Mesial Side															Distal Side													
	X1					X2					X1-X2					Y1					Y2					6)Y1-Y2			
	4	3	2	1		4	3	2	1		4	3	2	1		4	3	2	1		4	3	2	1		4	3	2	1
REC	n.s	n.s	n.s	n.s		n.s	≅HF ≅TFA	≠TFA ≅ HF	≅HF ≅TFA		n.s	≅HF ≠TFA	≅HF ≠TFA	≅HF ≠TFA		n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		n.s	n.s	≅HF ≠TFA	≅HF ≠TFA
HF	n.s	n.s	n.s	n.s		n.s	≠TFA ≅REC	≅ HF ≅ TFA	≠TFA ≅REC		n.s	=TFA ≅REC	≠TFA ≅REC	≠TFA ≅REC		n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		n.s	n.s	≠TFA ≅REC	≠TFA ≅REC
TFA	n.s	n.s	n.s	n.s		n.s	≠HF/ ≅REC	≠ REC = HF	≠HF/ ≅REC		n.s	=HF/ ≠REC	≠REC ≠HF	≠REC ≠HF		n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		n.s	n.s	≠REC ≠HF	≠REC ≠HF
P	0,71	0,48	0,76	0,88		0,42	0,00	0,03	0,02		0,12	0,01	0,00	0,00		0,93	0,98	0,65	0,75		0,97	0,52	0,30	0,29		0,30	0,27	0,00	0,00

* **n.s** ≅ No statistical differences were found in the intergroup comparison at the same level (Kruskal-Wallis test and Dunn. P>0.05).

Distobuccal Root –Apical Dentin Thickness

	Distobuccal canal –Apical Dentin Thickness																												
	Mesial Side															Distal Side													
	X1					X2					X1-X2					Y1					Y2					6)Y1-Y2			
	4	3	2	1		4	3	2	1		4	3	2	1		4	3	2	1		4	3	2	1		4	3	2	1
REC	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		≅HF ≠TFA	n.s	n.s	n.s		n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		n.s	≅HF ≠TFA	≅HF ≠TFA	n.s
HF	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		≅TFA/ ≅REC	n.s	n.s	n.s		n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		n.s	≠TFA ≅REC	≅TFA ≅REC	n.s
TFA	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		≠REC/≅HF	n.s	n.s	n.s		n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s		n.s	≠REC ≠HF	≠REC ≅HF	n.s
P	0,92	0,99	0,72	0,52		0,54	0,96	0,81	0,61		0,01	0,30	0,25	0,98		0,89	0,78	0,30	0,58		0,64	0,68	0,74	0,93		0,34	0,00	0,00	0,06

Apical Transportation

	Mesiobuccal canal – Apical Transportation					Distobuccal canal – Apical Transportation			
System/Level	**1**	**2**	**3**	**4**		**1**	**2**	**3**	**4**
Reciproc	n.s	n.s	≅ TFA ≠HF	≅ TFA ≠HF		n.s	≅HF ≠TFA	n.s	≠TFA ≅ HF
Hyflex CM	n.s	n.s	≅ TFA ≠REC	≅ TFA ≠REC		n.s	≅TFA ≅REC	n.s	≅ HF ≅ REC
TFA	n.s	n.s	≅ REC ≅ HF	≅ REC ≅ HF		n.s	≠REC ≅HF	n.s	≠REC ≅ HF
P	**0,20**	**0,09**	**0,00**	**0,00**		**0,06**	**0,04**	**0,41**	**0,04**

Coronal Transportation

	Mesiobuccal canal – Coronal Transportation					Distobuccal canal – Coronal Transportation			
System/Level	**-4**	**-3**	**-2**	**-1**		**-4**	**-3**	**-2**	**-1**
Reciproc	≅ TFA ≠HF	≠TFA ≅ HF	n.s	n.s		n.s	≅HF ≠TFA	≅HF ≠TFA	≅HF ≠TFA
Hyflex CM	≅ TFA ≠REC	≅ REC ≅ TFA	n.s	n.s		n.s	≅TFA ≅REC	≅TFA ≅REC	≠TFA ≅REC
TFA	≅ REC ≅ HF	≠ REC ≅ HF	n.s	n.s		n.s	≠REC ≅HF	≠REC ≅HF	≠REC ≠HF
P	**0,01**	**0,01**	**0,46**	**0,23**		**0,65**	**0,03**	**0,04**	**0,00**

Centering Ability of Apical Third

	Mesiobuccal canal – Centering ability					Distobuccal canal – Coronal Transportation			
Systems/Levels	**1**	**2**	**3**	**4**		**-4**	**-3**	**-2**	**-1**
Reciproc	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s
Hyflex CM	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s
TFA	n.s	n.s	n.s	n.s		n.s	n.s	n.s	n.s
P	**0,16**	**0,14**	**0,68**	**0,21**		**0,20**	**0,20**	**0,95**	**0,63**

Centering Ability of Coronal Third

	Mesiobuccal canal – Centering ability					Distobuccal canal – Centering ability			
Systems/Levels	**-4**	**-3**	**-2**	**-1**		**-4**	**-3**	**-2**	**-1**
Reciproc	n.s	n.s	n.s	n.s		≅HF ≅TFA	n.s	n.s	≅HF ≠TFA
Hyflex CM	n.s	n.s	n.s	n.s		≠TFA ≅REC	n.s	n.s	≠TFA ≅REC
TFA	n.s	n.s	n.s	n.s		≠HF ≅REC	n.s	n.s	≠HF ≠REC
P	**0,14**	**0,70**	**0,54**	**0,64**		**0,00**	**0,56**	**0,34**	**0,00**

Apical Volume

	Mesiobuccal canal – Apical Volume					Distobuccal canal – Apical Volume			
Systems/Levels	Initial volume	Final volume	Volume of dentin removed	Percentage of Removed dentin		Initial volume	Final volume	Volume of dentin removed	Percentage of Removed dentin
Reciproc	n.s	≠TFA ≅ HF	≠TFA ≅ HF	≠TFA ≅ HF		n.s	≠TFA ≅ HF	≠TFA ≅ HF	≠TFA ≅ HF
Hyflex CM	n.s	≅ REC ≠ TFA	≅ REC ≠ TFA	≅ REC ≅ TFA		n.s	≅ REC ≠ TFA	≅ REC ≠ TFA	≅ REC ≠ TFA
TFA	n.s	≠ REC ≠ HF	≠ REC ≠ HF	≠ REC ≅ HF		n.s	≠ REC ≠ HF	≠ REC ≠ HF	≠ REC ≠ HF
P	**0,78**	**0,00**	**0,00**	**0,03**		**0,97**	**0,00**	**0,00**	**0,01**

Whole Volume

	Mesiobuccal canal –Entire Volume					Distobuccal canal – Entire Volume			
Systems/Levels	Initial volume	Final volume	Volume of dentin removed	Percentage of dentin removed		Initial volume	Final volume	Volume of dentin removed	Percentage of dentin removed
Reciproc	**n.s**	**≅ HF** **≅ TFA**	**≅ HF** **≠ TFA**	**≅ HF** **≠ TFA**		**n.s**	**≠TFA** **≅ HF**	**≠TFA** **≅ HF**	**≠TFA** **≅ HF**
Hyflex CM	**n.s**	**≅ REC** **≠ TFA**	**≅ REC** **≠ TFA**	**≅ REC** **≠ TFA**		**n.s**	**≅ HF** **≅ TFA**	**≅ REC** **≠ TFA**	**≅ REC** **≠ TFA**
TFA	**n.s**	**≅ REC** **≠ HF**	**≠ HF** **≠ REC**	**≠ HF** **≠ REC**		**n.s**	**≠ REC** **= HF**	**≠ REC** **≠ HF**	**≠ REC** **≠ HF**
P	**0,44**	**0,03**	**0,00**	**0,00**		**0,82**	**0,04**	**0,00**	**0,00**

SHAPING TIME

Systems/Level	Mesiobuccal Canal	Distobuccal Canal
Reciproc	**≅ HF** **≠ TFA**	**n.s**
Hyflex CM	**≅ REC** **≠ TFA**	**n.s**
TFA	**≠ HF** **≠ REC**	**n.s**
P	**0,05**	**0,52**

ATTACHMENTS

ATTACHMENT A

FACULDADE DE ODONTOLOGIA DE BAURU-USP

PARECER CONSUBSTANCIADO DO CEP

DADOS DO PROJETO DE PESQUISA

Título da Pesquisa: AVALIAÇÃO DE 3 TIPOS DE LIGAS DE NITI SUBMETIDAS A CICLOS REPETIDOS DE ESTERILIZAÇÃO E LIMPEZA: ANÁLISE DA GEOMETRIA DO PREPARO DO CANAL RADICULAR, DO TEMPO EFETIVO DE PREPARO DO CANAL RADICULAR E DAS CARACTERÍSTICAS ESTRUTURAIS DO INSTRUMENTO

Pesquisador: Ericson Janolio de Camargo

Área Temática:

Versão: 1

CAAE: 46767515.2.0000.5417

Instituição Proponente: Universidade de São Paulo - Faculdade de Odontologia de Bauru

Patrocinador Principal: Financiamento Próprio

DADOS DO PARECER

Número do Parecer: 1.173.071

Data da Relatoria: 29/07/2015

Apresentação do Projeto:

Trata-se de projeto de Pesquisa acima intitulado de autoria do Pesquisador Ericson Janolio de Camargo e que tem como objetivo avaliar a influência de 3 tipos de ligas de sistemas de preparo do canal radicular realizadas em raízes vestibulares de

molares superiores, após cada uso, totalizando cinco usos, simulando as condições clínicas que empregam limpeza e esterilização sucessiva de instrumentos. Para realização da pesquisa serão analisados 3 parâmetros: as alterações morfológicas da anatomia interna de canais submetidos ao preparo biomecânico analisados por meio da microtomografia computadorizada (Micro CT), o tempo efetivo de trabalho durante o preparo biomecânico avaliado por meio de cronômetro digital e análise do instrumento por meio da avaliação superficial, empregando a microscopia eletrônica de varredura (MEV) e análise das propriedades químicas do instrumento, por meio da Espectroscopia por Energia Dispersiva de raio-X (EDS). O total de 75 molares superiores humanos extraídos serão selecionados e divididos em 3 grupos com 25 espécimes cada. O critério de inclusão na amostra será a presença dos graus de curvatura das raízes mésio-vestibular e disto-vestibular, entre 20º a 30º e entre 0º a 5º, respectivamente, conforme preconizado por Weine (1982). Para o grupo I (M-Wire): realizar-se-á instrumentação com o sistema Reciproc (R); para o

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grupo II (CM-Wire) com o sistema Hyflex (HF) e para o grupo III (Fase R), com o TF Adaptive (TFA). Serão utilizadas 5 caixas de cada sistema para o preparo dos canais mesio-vestibular e distovestibular. Inicialmente, os instrumentos serão analisados em M.E.V., com aumento de 35 vezes e analisados em EDS, e em seguida, passarão por um protocolo de limpeza baseado no proposto por Parashos, Linsuwanont e Messer (2004), previamente à esterilização. Durante o preparo biomecânico, será analisado o tempo efetivo necessário ao preparo do canal radicular. Após o preparo do canal, serão avaliados: a configuração anatômica do canal (avaliação da espessura mínima de dentina remanescente, transporte do canal, volume total e apical), a análise superficial e a análise das propriedades químicas dos instrumentos. Estes procedimentos serão realizados antes e após cada uso do instrumento até o quinto uso.
Os dados serão submetidos à análise estatística com nível de significância a 5%.

Objetivo da Pesquisa:
Objetivo Primário:
O mercado endodôntico atual tem lançado novos instrumentos periodicamente com diferentes tratamentos da liga do metal. Estas alterações visam a melhorar algumas limitações deste instrumental, em especial, àquelas relacionadas ao maior respeito à anatomia original do canal, maior segurança e eficiência durante o uso deste tipo de material.Devido à diferença na composição das ligas apresentadas por esses instrumentos endodônticos (M-Wire, Fase R e CM) e a carência de estudos que imitem as condições clínicas como os ciclos repetitivos de limpeza, esterilização e uso, justifica-se um estudo mais aprofundado e elucidativo sobre o real comportamento desses materiais quanto à geometria do canal radicular produzida no preparo biomecânico, quanto ao tempo efetivo do preparo do canal e quanto à análise estrutural desses instrumentos submetidos a essas condições.
Objetivo Secundário:
Este trabalho tem como objetivo avaliar 3 tipos de ligas de NiTi (M-Wire, Fase R e CM-Wire) quanto às características geométricas do canal radicular pré e pós instrumentação, quanto ao tempo efetivo de preparo biomecânico com estes sistemas e as características químico-estruturais destas ligas quando submetidas à influência de ciclos sucessivos de limpeza e esterilização.

Avaliação dos Riscos e Benefícios:
Riscos:
Informa o pesquisador que não há riscos.
Benefícios:
Inerentes à proposta do projeto, conhecer o comportamento dos instrumentos frente aos quesitos

avaliados.

Comentários e Considerações sobre a Pesquisa:

Não há.

Considerações sobre os Termos de apresentação obrigatória:

Todos os documentos foram apresentados corretamente.

Recomendações:

Não há.

Conclusões ou Pendências e Lista de Inadequações:

Tendo em vista a apresentação de todos os documentos de forma satisfatória, sou de parecer favorável a aprovação do projeto de pesquisa.

Situação do Parecer:

Aprovado

Necessita Apreciação da CONEP:

Não

Considerações Finais a critério do CEP:

Esse projeto foi considerado APROVADO na reunião extraordinária do CEP de 29.07.2015, com base nas normas éticas da Resolução CNS 466/12. Ao término da pesquisa o CEP-FOB/USP exige a apresentação de relatório final. Os relatórios parciais deverão estar de acordo com o cronograma e/ou parecer emitido pelo CEP. Alterações na metodologia, título, inclusão ou exclusão de autores, cronograma e quaisquer outras mudanças que sejam significativas deverão ser previamente comunicadas a este CEP sob risco de não aprovação do relatório final. Quando da apresentação deste, deverão ser incluídos todos os TCLEs e/ou termos de doação assinados e rubricados, se pertinentes.

FACULDADE DE ODONTOLOGIA DE BAURU-USP

Plataforma Brasil

Continuação do Parecer: 1.173.071

BAURU, 06 de Agosto de 2015

Assinado por:
Izabel Regina Fischer Rubira Bullen
(Coordenador)

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