UNIVERSIDADE FEDERAL DE GOIÁS
PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA

André Luiz Gomide de Morais

Comparação do Comprimento de Trabalho do Canal Radicular Usando Tomografia Computadorizada de Feixe Cônico, Radiografia Periapical e Localizador Apical Eletrônico

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Trabalho apresentado para defesa de dissertação de Mestrado ao Programa de Pós-Graduação em Odontologia da Universidade Federal de Goiás.

Orientador: Prof. Dr. Carlos Estrela

Co-orientadora: Profª Dra. Ana Helena G. Alencar

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BANCA EXAMINADORA DA DISSERTAÇÃO DE MESTRADO

Aluno: André Luiz Gomide de Morais

Orientador: Prof. Dr. Carlos Estrela

Co-orientadora: Profª. Drª. Ana Helena Gonçalves de Alencar

Membros:

1. Prof. Dr. Carlos Estrela (UFG)

2. Profª. Drª Ana Helena Gonçalves de Alencar (UFG)

3. Prof. Dr. Álvaro Henrique Borges (UNIC)

Suplente:

1. Prof. Drª. Lílian de Fátima Guedes Amorim (UFG)

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DEDICATÓRIA

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SUMÁRIO

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LISTA DE ABREVIATURAS, SIGLAS E SÍMBOLOS

TCFC	Tomografia computadorizada de feixe cônico
CBCT	*Cone beam computed tomography*
p, α	Nível de significância / *significance level*
USA	*United States of America*
EUA	Estados Unidos da América
PA	*Pensylvania*
WA	*Washington*
MI	*Michigan*
IL	*Illinois*
kVp	Quilovoltagem / *Peak kilovoltage*
mA	Miliampere / *milliampere*
mm	Milímetro / *millimeter*
Ghz	Gigahertz
K	Lima endodôntica do tipo Kerr
PA	Periodontite apical
AP	*Apical periodontitis*
NaOCl	Hipoclorito de sódio / *Sodium hypochlorite*
SP	São Paulo
NY	Nova Iorque / *New York*
SPSS	*Statistical Package for the Social Sciences*
M	Média
A	*Average*

DP	Desvio-padrão
SD	*Standard Deviation*
Co.	*Company*
mL	Mililitro
Ω	Ohm

RESUMO

Introdução: Estratégias para obtenção do comprimento de trabalho para preparar e obturar canais radiculares têm sido tema relevante de discussão em Endodontia. O objetivo deste estudo foi comparar *in vivo* as medidas de comprimento de trabalho do canal radicular determinadas por meio da tomografia computadorizada de feixe cônico (TCFC) com as obtidas por meio de radiografia periapical e localizador apical eletrônico. **Metodologia:** Foram avaliados os comprimentos de trabalho dos canais radiculares em 30 dentes de 19 pacientes com diagnóstico de periodontite apical. Radiografias periapicais iniciais de diagnóstico e plano de tratamento, empregando a técnica do paralelismo, foram realizadas. As imagens de TCFC foram obtidas usando o sistema i-CAT (com o intuito de diagnosticar os casos de periodontite apical que se mostraram complexos ou duvidosos) e foram medidas a partir de função específica do programa desse sistema. Foi realizada a abertura coronária, os canais radiculares foram irrigados solução de hipoclorito de sódio a 2,5%, sendo realizada a exploração e o esvaziamento inicial do canal radicular. Depois foi realizado o preparo do orifício de entrada e do terço cervical da raiz. O forame apical foi localizado usando o localizador Root ZX® por meio do avanço de uma lima tipo K-file que melhor se adaptasse ao canal radicular de aço inoxidável no canal radicular, de acordo com instruções do fabricante. A medida radiográfica foi feita por meio da colocação de uma lima tipo K-file de aço inoxidável no canal radicular, até que sua ponta estivesse a 1,0mm do ápice radicular (determinado pelas medidas obtidas com o localizador apical eletrônico). Essas três medidas de comprimento de trabalho foram tabuladas e comparadas. O teste de Kruskal-Wallis foi empregado para analisar as diferenças entre os métodos de obtenção dos comprimentos de trabalho. O nível de significância foi estabelecido em $\alpha=5\%$. **Resultados:** O valor médio e os desvios-padrões para a determinação do comprimento de trabalho por meio de imagens de TCFC, localizador apical eletrônico e radiografia periapical foram de e 21,4 ± 2,7, 21,5 ± 3,1, 21,32 ± 3, respectivamente. Diferenças significantes entre as medidas obtidas pelos três métodos não foram verificadas ($p>0.05$). **Conclusões:** A determinação do comprimento de trabalho em imagens de TCFC mostrou ser tão similar quanto às determinações obtidas por meio do método radiográfico e do localizador apical eletrônico.

Palavras-Chave: odontometria, tomografia computadorizada de feixe cônico, radiografia dentária, ápice dentário, localizador apical eletrônico, limite apical.

ABSTRACT

Introduction Strategies to obtain the working length to prepare and fill the root canals has been relevant theme of discussion in endodontics. The purpose of this study was to compare in vivo the canal root working length measures determined by cone beam computed tomography (CBCT) images with the ones obtained by using periapical radiograph and electronic apex locator. **Methods** The root canal working lengths of 30 single-rooted teeth from 19 patients whose diagnosis was apical periodontitis were evaluated. Initial periapical radiographs for diagnosis and treatment planning, employing the parallelism technique, were taken. CBCT images were acquired with i-CAT system (aiming of diagnosing the cases of apical periodontitis that showed to be complex and doubtful) and measured with specific function of i-CAT software. The coronal opening was made, the root canals were irrigated with sodium hypochlorite solution 2.5%, being performed the exploration and initial emptying of root canal. After, the preparation of the inlet orifice and of the cervical root third was carried out . The minor foramen was located using Root ZX® locator by advancing a stainless steel K-file that best suited the root canal, according to the manufacturer´s instructions. The radiographic measurement was made by advancing a stainless steel K-file in the root canal, until its tip was 1.0 mm from the root apex (determined from the measures obtained by the electronic ape locator). These 3 working length were tabulated and compared. Kruskal-Wallis test was used to analyze the differences between working lengths methods. The significance was set at α=5%. **Results** The mean values and standard deviations for working length determination by electronic apex locator, periapical radiograph and CBCT images were 21.5 ± 3.1, 21.32 ± 3, 21.4 ± 2.7, respectively. Significant differences were not verified statistically ($P>0.05$). **Conclusions** CBCT images working length determination showed to be as similar as the determinations obtained by using periapical radiograph and electronic apex locator.

Keywords: odontometry, cone beam computed tomography, dental radiography, tooth apex, electronic apex locator, apical limit.

1. INTRODUÇÃO

A complexidade anatômica do terço apical dos canais radiculares pode dificultar a terapia endodôntica nos casos de dentes com periodontite apical[82]. A eliminação de micro-organismos depende da sequência dos passos operatórios, tais como abertura coronária, processo de sanificação do canal radicular e obturação[84]. A Endodontia Contemporânea tem como desafio um melhor entendimento das variações observadas na anatomia interna dos canais radiculares, das estratégias de obtenção do comprimento de trabalho para o preparo e da seleção de métodos antimicrobianos para desorganizar o biofilme bacteriano[19].

O prognóstico da terapia endodôntica tem sido influenciado pelo limite apical de instrumentação e obturação. Kojima *et al.* (2004) e Schaeffer *et al.* (2005), a partir de uma meta-análise, discutiram o limite ideal para o término da instrumentação e obturação do canal radicular. Foi determinada a influência desse limite apical, da condição patológica pulpar e da condição periodontal no prognóstico endodôntico. Uma maior taxa de sucesso foi observada quando o tratamento incluía o limite de obturação aquém do ápice radiográfico.

Os métodos radiográficos representam a preferência da maioria dos profissionais para a determinação do comprimento de trabalho[6,8,14,72,73]. Muito embora a técnica do paralelismo produza menores alterações durante a obtenção da imagem radiográfica, o filme ideal e a orientação do tubo de raios-X são aspectos difíceis de se padronizar[7,37,44]. As imagens radiográficas distorcidas (alongadas ou encurtadas) podem resultar de erros no posicionamento vertical do filme ou da angulação do posicionador radiográfico[23,37]. Mudanças no ângulo entre o filme radiográfico e o dente têm um efeito significante em medidas lineares baseadas nas radiografias periapicais[9,23,60].

Vários equipamentos foram desenvolvidos com o intuito de encontrar o comprimento mais adequado para instrumentação e obturação dos canais radiculares. Os localizadores apicais eletrônicos foram concebidos para reduzir o número de radiografias utilizadas durante o tratamento endodôntico e minimizar a subjetividade envolvida na interpretação radiográfica[35]. O desenvolvimento de novas tecnologias teve o objetivo de tornar a terapia endodôntica mais racional, com menor estresse para o profissional, tornando-a mais precisa[28,35,38].

Custer (1918) apresentou um sistema elétrico para localização do término do canal radicular baseado no princípio de que a condutividade elétrica dos tecidos ao redor do ápice radicular era maior do que a condutividade dentro do sistema de canais radiculares, no sentido da coroa ao ápice. Suzuki (1942) indicou que a resistência elétrica entre o instrumento introduzido no canal radicular e o eletrodo colocado na mucosa oral registra valores consistentes. Sunada (1962) determinou que, quando a ponta do instrumento endodôntico alcança a membrana periodontal pelo forame apical, a resistência elétrica entre o instrumento e a mucosa oral era de aproximadamente 6,5 kΩ.

No entanto, outros estudos[24,31,32,51,52,76,78,80] foram desenvolvidos no sentido de aprimorar essa ideia inicial e tentar encontrar o meio mais adequado de se localizar a constrição apical, que seria o limite ideal onde a instrumentação e a obturação deveriam terminar. Diferentes equipamentos foram idealizados para esse fim, tendo no mercado vários princípios de operação, tais como os aparelhos de medição eletrônica do comprimento do canal radicular baseados na resistência, na oscilação de baixa frequência, aparelhos de alta frequência, de capacitância e resistência, equipamentos baseados no gradiente de voltagem, em duas frequências e diferença de impedância, em duas frequências e razão de impedância e em multifrequências de impedância[58].

Os atuais localizadores apicais avaliam a diferença da impedância entre duas frequências, ou a razão entre duas impedâncias elétricas[49]. Esses aparelhos foram desenvolvidos por Saito & Yamashita (1990) e Kobayashi & Suda (1994), respectivamente. Observou-se maior precisão desses equipamentos quando comparados àqueles desenvolvidos na década de 80, principalmente no que se refere à presença de exsudato, sangue ou outro tipo de líquido[39].

A precisão dos aparelhos de mensuração eletrônica tem sido objeto de alguns estudos[28,29,45,77,81]. O Root ZX® (J. Morita Corp., Tóquio, Japão) tem demonstrado ser um equipamento com bons resultados[28,77], no que diz respeito à localização da constrição apical, o que representa a transição entre o tecido pulpar e o periodontal apical, ponto de referência em que a instrumentação endodôntica e a obturação deveriam preferencialmente terminar[16,62,64].

Novas modalidades de imagem têm sido incluídas na prática clínica, tais como a radiografia digital, a densitometria, a tomografia computadorizada, a ressonância magnética, a ultrassonografia e técnicas nucleares[3,12,13,17,18,30]. Essas imagens com detalhes apresentam alta resolução das estruturas bucais e permitem a detecção precoce de alterações nas estruturas maxilofaciais[20]. A tomografia computadorizada de feixe cônico (TCFC) representa uma importante tecnologia recentemente introduzida na Odontologia[3,55], com elevado potencial para aplicação clínica e acurácia quando comparada com a radiografia periapical. Verifica-se sua contribuição no plano de tratamento, diagnóstico, tratamento e prognóstico de diferentes doenças, além de valor em pesquisas[5,10,17,18].

Algumas aplicações dessa tecnologia da TCFC especificamente em Endodontia incluem diagnóstico de patologias endodônticas, análise da morfologia do canal radicular, de patologias de origem não-endodôntica, avaliação de fraturas radiculares e traumas, análise de reabsorção radicular interna e externa e reabsorção cervical invasiva, além de planejamento pré-cirúrgico[13,18].

Outro aspecto importante relaciona-se ao *software* que permite determinar distâncias lineares e volume de estruturas anatômicas[5,70], favorecendo o planejamento pré-operatório de lesões maxilofaciais[11], a determinação do nível ósseo marginal com vistas ao tratamento ortodôntico[47], técnicas de reconstrução[1,46], alterações no nível ósseo após terapia regenerativa periodontal[27], defeito periodontal[34], lesões periapicais[17,18] e reabsorções radiculares[21].

A hipótese nula deste estudo relaciona-se à ausência de diferenças entre a medida do comprimento de trabalho obtida por meio das imagens de TCFC, radiografias periapicais e localizador apical eletrônico. Desta forma, o objetivo do estudo foi comparar *in vivo* o comprimento de trabalho determinado por meio da TCFC com o obtido por meio de radiografia periapical e localizador apical eletrônico.

2. JUSTIFICATIVA

O presente trabalho levou em consideração:

1. a necessidade de adequada determinação do comprimento de trabalho para o preparo e obturação de canais radiculares com vistas a um prognóstico favorável da terapia endodôntica;
2. o potencial de aquisição de imagem tridimensional em alta resolução obtida com TCFC e sua precisão como ferramenta de mensuração de distâncias lineares;
3. a eficiência dos localizadores apicais eletrônicos;
4. a carência de estudos que avaliassem os recursos para a determinação do comprimento de trabalho do canal radicular em imagem de TCFC comparados com a radiografia periapical e com o localizador eletrônico apical.

3. OBJETIVO

Comparar as medidas de comprimento de trabalho do canal radicular determinadas por meio da TCFC com as obtidas por meio de radiografia periapical e localizador apical eletrônico.

4. METODOLOGIA

Pacientes

Este estudo clínico avaliou o comprimento de trabalho de canais radiculares de 30 dentes unirradiculares (13 incisivos centrais superiores, 14 incisivos laterais superiores e 3 caninos superiores). O diagnóstico foi de periodontite apical assintomática associada à infecção primária e cavidade fechada, de 19 pacientes (12 homens e 7 mulheres, média de idade de 33,8 anos) provenientes da clínica de Estágio em Urgência da Faculdade de Odontologia da Universidade Federal de Goiás, Brasil.

Todas as imagens e dados para análise deste estudo foram obtidos a partir de um banco de dados provenientes de outro estudo intitulado "Processo de reparo da periodontite apical por análise densitométrica com tomografia computadorizada cone beam em função de estratégias terapêuticas diferentes".

As imagens de TCFC foram obtidas em todos os pacientes com o propósito de diagnóstico de lesões periapicais que se mostrou complexo e duvidoso (conforme orientação da Associação Americana de Endodontistas e Academia Americana de Radiologia Oral e Maxilofacial[2]), e para plano de tratamento.

Este estudo foi aprovado pelo Comitê de Ética em Pesquisa da Universidade Federal de Goiás sob o protocolo nº 171/2009. Todos os pacientes foram informados sobre o objetivo do estudo e assinaram um termo de consentimento livre e esclarecido.

Aquisição das imagens radiográficas

Inicialmente foram obtidas imagens radiográficas de todos os dentes para o diagnóstico e o plano de tratamento. A técnica do paralelismo foi empregada valendo-se de posicionadores radiográficos, no intuito de minimizar as distorções causadas por erros de angulações. No estudo foram incluídos os dentes com: ausência de calcificações dos canais radiculares, reabsorções internas ou externas e presença de ápices radiculares completamente formados.

Todas as radiografias periapicais foram obtidas com o uso de aparelho Spectro 70X (Dabi Atlante, Ribeirão Preto, SP, Brasil), com tubo focal de 0,8 mm X 0,8 mm, filmes Kodak Insight-E (Eastman Kodak Co, Rochester, NY, EUA). Todos os filmes foram processados em uma processadora automática.

Aquisição das imagens de TCFC

As imagens por TCFC foram obtidas com o sistema i-CAT (Imaging Sciences International, Hatfield, PA, EUA). Os volumes foram reconstruídos com 0,2mm de voxel isométrico, tensão de tubo de 120kVp e corrente do tubo de 3,8mA. O tempo de exposição foi de 40 segundos. As imagens foram analisadas com o próprio programa do tomógrafo (Xoran versão 3.1.62; Xoran Technologies, Ann Arbor, MI, EUA), em um computador com sistema operacional Microsoft Windows XP Professional SP-2 (Microsoft Corp., Redmond, WA, EUA), com processador Intel® Core™ 2 Duo 1,86Ghz-6300 (Intel Corporation, EUA), placa de vídeo NVIDIA GeForce 6200 turbo cache (NVIDIA Corporation, EUA) e monitor EIZO - S2000 FlexScan, resolução de 1600x1200 pixels (EIZO Nanao Corporation Hakusan, Japão).

Medidas das Imagens de TCFC

O método utilizado para estudar a determinação do comprimento de trabalho dos canais radiculares em imagens de TCFC baseou-se na delimitação e mensuração da distância entre pontos anatômicos correspondentes às coroas e aos ápices das raízes dentárias. Todas as medidas nas imagens foram realizadas por um especialista em radiologia odontológica, utilizando a ferramenta de mensuração do próprio programa do tomógrafo (Xoran 3.1.62; Xoran Technologies, Ann Arbor, MI, USA). Foi utilizada uma função específica do programa do i-CAT, que oferece valores em milímetros para delimitar as medidas das imagens dos dentes. As mensurações foram efetuadas no plano sagital (o referencial utilizado foi a maior extensão da medida, valendo-se da estratégia de navegação do sistema). A distância de referência para as aquisições das medidas foi a extensão máxima entre a borda incisal ou o topo da cúspide e o ponto mais apical da raiz (Fig. 1D-I) . A medida considerada foi 1 mm aquém do ápice radicular.

Determinação do Comprimento de Trabalho do Canal Radicular

A abertura coronária foi feita usando pontas diamantadas números 1012 e 2200 (KG Sorensen, Agerskov, Dinamarca). Posterior à abertura coronária, os canais radiculares foram irrigados com 5 mL solução de hipoclorito de sódio a 2,5% e seu conteúdo era aspirado. A câmara coronária foi completamente preenchida pela mesma solução (NaOCl a 2,5%), sendo realizada a exploração e o esvaziamento inicial do canal radicular, usando lima endodôntica de aço inoxidável do tipo K-File número 15 (Dentsply-Maillefer, Ballaigues, Suíça). O preparo do orifício de entrada e do terço cervical da raiz foi feito usando brocas de Gates-Glidden números 2 e 3 e de Largo números 1 e 2.

Em seguida, o comprimento de trabalho foi determinado, usando um localizador apical eletrônico, como segue: a constrição apical era localizada utilizando o localizador Root ZX® (J. Morita Corp. 2004) por meio do avanço gradual da lima de aço inoxidável que mais se ajustasse ao canal radicular de acordo com as instruções do fabricante. A alça labial foi posicionada no lábio do paciente e a parte porta-limas era ligada à lima. O instrumento foi avançando lentamente para dentro do canal radicular até a leitura do monitor indicar a palavra “APEX” e um sinal sonoro contínuo indicando que o ápice anatômico tinha sido alcançado. O marcador de silicone inserido na lima foi colocado no ponto de referência da anatomia dentária, a lima foi retirada e a distância entre o marcador e a ponta da lima foi medida usando uma régua milimetrada. Em seguida, o marcador de silicone era recuado em 1 mm e a medida anotada.

A odontometria pela radiografia foi realizada por meio da introdução da lima de aço inoxidável do tipo K-File que mais se ajustasse dentro do canal radicular na medida de 1 mm aquém do ápice radicular (determinada por meio da medida obtida com o localizador apical eletrônico). A radiografia foi realizada, e quando a ponta da lima não se encontrava a 1 mm aquém do ápice radiográfico, esta era reposicionada e outra radiografia era obtida para garantir que ela estivesse na medida adequada. A medida da distância entre o marcador e a ponta da lima era anotada (Fig. 1A-C). Essa imagem foi obtida por meio da técnica do paralelismo.

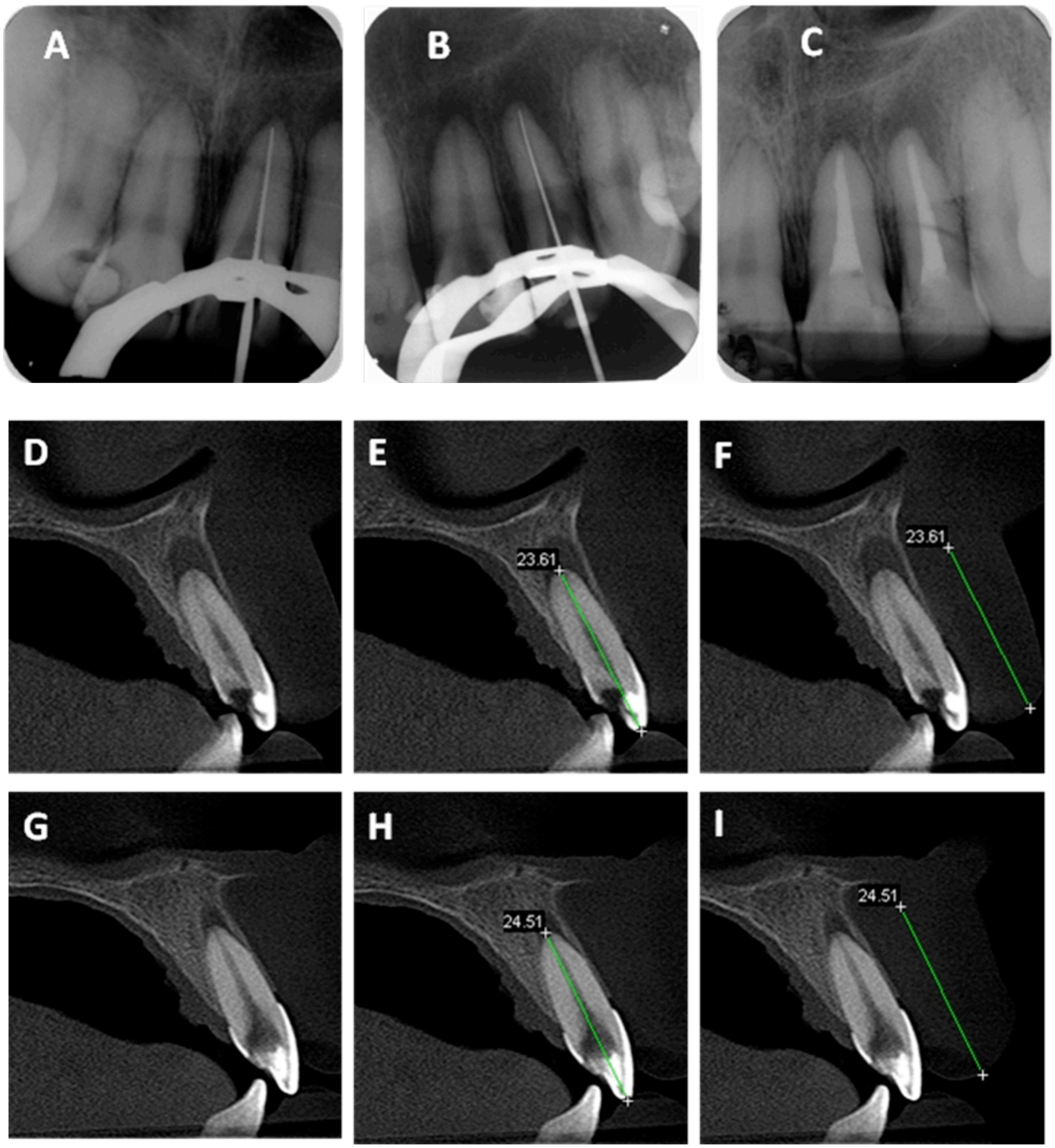

Figura 1. Caso clínico mostrando a obtenção do comprimento de trabalho dos incisivos central (dente 11) e lateral superiores (dente 12) usando radiografias periapicais (A-B) e imagens de TCFC num corte sagital (D-I)

Análise Estatística

O teste de Kruskal-Wallis foi utilizado para analisar as diferenças entre as medidas de trabalho obtidas usando a TCFC, as medidas radiográficas e as do localizador apical eletrônico (SPSS Statistics for Windows 19.0 - SPSS Inc., Chicago, IL, EUA). Para determinar se inicialmente os dados eram paramétricos ou não, o teste de Levene foi utilizado. O nível de significância foi definido em $\alpha=5\%$.

5. RESULTADOS

Os valores médios e os desvios-padrões para determinação do comprimento de trabalho obtida pela TCFC, pelo localizador apical e pela radiografia periapical foram, respectivamente, 21,4 ± 2,7, 21,5 ± 3,1 e 21,32 ± 3 (Tabela 1). Nenhuma diferença estatisticamente significante foi verificada entre as medidas obtidas pelos três métodos ($p>0,05$).

Tabela 1. Médias e desvios-padrões das medidas do comprimento de trabalho do canal radicular obtidas por TCFC, localizador apical eletrônico, radiografia periapical.

TCFC	**Localizador**	**Radiografia**	**P**
M ± DP	**M ± DP**	**M ± DP**	
21,4 ± 2,7	21,5 ± 3,1	21,32 ± 3	0,95

M – Média
DP – Desvio-padrão

6. DISCUSSÃO

Vários fatores podem ser responsáveis pelo sucesso ou fracasso do tratamento endodôntico. A etiologia da patologia pós-tratamento endodôntico relaciona-se a fatores importantes, tais como os microbianos (infecções intrarradicular e extrarradicular - bactérias, fungos) e os não microbianos (endógenos - cistos verdadeiros; exógenos - reação de corpo estranho)[57]. A qualidade do processo de sanificação, o preenchimento tridimensional e uma boa restauração coronária constituem procedimentos que influenciam o sucesso, sendo que o prognóstico pode ser afetado pela sobreobturação ou por uma obturação aquém do limite[19,22,41,54,56,57,61,65,67,83,84]. Um aspecto importante que requer bastante atenção relaciona-se com a escolha do limite apical mais apropriado para preparar e obturar os canais radiculares.

Diferentes técnicas têm sido usadas para determinar a posição do forame apical e assim possibilitar a mensuração do comprimento de trabalho dos canais radiculares. O método mais empregado tem envolvido as radiografias periapicais. Entretanto, apesar de ser aceito que a constrição apical está em média localizada a 0,5-1,0mm do ápice radiográfico[36,53], verificam-se variações na relação desse ponto de referência que resultam em erros de instrumentação, e que obviamente influenciam na posição da obturação endodôntica[59,71]. Referências das estruturas anatômicas visualizadas nas radiografias podem mostrar-se ocultas[15,25,26,43].

Aparelhos eletrônicos para detecção do término do canal radicular representam importantes inovações no tratamento endodôntico[50]. A operacionalidade desses equipamentos está baseada no fato de que a condutividade elétrica dos tecidos circundantes do ápice do radicular é maior que a condutividade dentro do sistema de canais radiculares estando o canal seco ou preenchido por fluido não-condutivo[14,58].

Os valores médios e os desvios-padrões para determinação do comprimento de trabalho obtidos pelo localizador apical, pela radiografia periapical e pela TCFC foram, respectivamente, 21,5 ± 3,1, 21,32 ± 3 e 21,4 ± 2,7 (Tabela 1). Nenhuma diferença estatisticamente significante foi verificada entre as medidas obtidas pelos três métodos ($p>0.05$). Estes resultados estão em conformidade com estudos anteriores[33,48,69]. Janner *et al.* (2011), em estudo-piloto, avaliaram a utilidade e a precisão das já existentes varreduras de TCFC em medir o comprimento endodôntico de trabalho e compararam com o padrão de procedimentos clínicos. Nos três pacientes incluídos, 9 dentes com um total de 10 canais radiculares foram tratados. Para esses canais radiculares, uma forte correlação foi encontrada entre o comprimento de trabalho endodôntico, a medida nas imagens de TCFC e as medições obtidas pelo localizador apical eletrônico. Sherrard *et al.* (2010) avaliaram a precisão e a confiabilidade das medidas do comprimento do dente e do comprimento da raiz derivadas de dados volumétricos de TCFC realizadas em 7 crânios de suínos. As imagens de TCFC foram pelo menos tão precisas e confiáveis quanto as radiografias periapicais para a determinação dos comprimentos dos dentes. Maret *et al.* (2010) verificaram em germes dentários que os volumes obtidos com a TCFC e com a microtomografia computadorizada foram estatisticamente semelhantes. Desvios geométricos entre reconstruções tridimensionais da superfície da TCFC e da microtomografia computadorizada não mostraram áreas de erros importantes e sistemáticos. Diferenças entre o comprimento da obturação do canal radicular, detectado por radiografia periapical, e imagens da TCFC foram identificadas por Moura *et al.* (2009). Radiografias periapicais mostraram que obturações do canal radicular estiveram de 1-2 mm aquém do ápice em 88%, 89,3% e 95% dos dentes anteriores, pré-molares e molares, respectivamente. As imagens da TCFC mostraram obturações que tinham o mesmo comprimento em 70%, 73,7% e 79% dos dentes anteriores, pré-molares e molares, respectivamente. A frequência de periodontite apical foi significativamente maior nos molares do que em outros grupos de dentes, independentemente do método de diagnóstico.

Apesar de os benefícios e limitações da radiografia periapical serem bem conhecidos por representar um recurso comumente usado para a determinação do comprimento de trabalho do canal radicular, muitos profissionais têm dado preferência ao uso do localizador apical eletrônico. Estudos *in vivo* têm discutido seu desempenho[38,63,68,79]. Shabahang *et al.* (1996) verificaram que o Root ZX® foi capaz de localizar o forame em 25 dentes com uma precisão clínica de 96,2%. Ravanshad *et al.* (2010) compararam o efeito da determinação do comprimento de trabalho utilizando o localizador apical eletrônico ou radiografia sobre a adequação do comprimento de trabalho final, bem como a obturação final, em um total de 84 pacientes. O tratamento endodôntico utilizando o localizador apical eletrônico foi comparável, se não superior, à medida do comprimento radiográfico com relação aos casos aceitáveis e de obturação aquém da medida.

Vieyra *et al.* (2010) avaliaram a precisão dos localizadores apicais eletrônicos Root ZX® e Elements-Diagnostic® quando comparados com as radiografias para localizar o término do canal ou a constrição apical de 482 canais radiculares. Não houve diferença significativa entre os dois localizadores, porém houve diferença significativa entre eles e a radiografia. Localizar o forame apical usando os dois localizadores apicais foi mais preciso do que as radiografias, o que poderia reduzir o risco de instrumentação e obturação além do forame apical. Todavia, deve-se considerar que em condições clínicas associadas a fenômenos biológicos, tais como inflamação, podem ainda ter um efeito na acurácia dos localizadores apicais eletrônicos[42]. Tecido vital intacto, exsudato inflamatório e sangue podem conduzir corrente elétrica e causar leituras imprecisas, tanto que a presença desses fatores deve ser minimizada antes das leituras pelos localizadores[24,75]. Outros condutores que podem causar um curto-circuito são as restaurações metálicas, cáries, saliva e instrumentos num canal secundário. Um cuidado adicional deve ser tomado caso exista alguma dessas variáveis[24,74]. O acúmulo de debris de dentina no ápice e as calcificações podem também afetar a determinação precisa do comprimento de trabalho com os localizadores apicais eletrônicos[4,24]. Desta forma, o emprego desses equipamentos tem se mostrado com algumas limitações.

A influência da determinação dos limites apicais para o preparo do canal radicular e obturação no resultado de um tratamento de canal radicular e os recursos disponíveis para avaliar corretamente a extensão de trabalho do canal radicular têm sido objeto de constante discussão[22,41,61,65,67]. Os critérios de sucesso do tratamento do canal radicular devem ser revistos a partir dos resultados alcançados com novas tecnologias, como a TCFC[18,83]. Considerações importantes foram feitas por Wu *et al.* (2009) sobre as limitações das revisões sistemáticas anteriormente publicadas avaliando o resultado do tratamento endodôntico. Tradicionalmente, a radiografia periapical tem sido empregada para avaliar o resultado do tratamento do canal radicular. A ausência de uma radioluscência periapical tem sido considerada uma confirmação de um periápice saudável. No entanto, uma elevada percentagem de casos confirmados como saudáveis por radiografias revelaram-se com periodontites apicais em TCFC e pelo exame histológico. As sérias limitações de estudos clínicos longitudinais restringem a interpretação correta dos resultados do tratamento endodôntico. Os resultados do tratamento endodôntico deveriam ser reavaliados em estudos longitudinais de longo prazo usando a TCFC e critérios mais rigorosos de avaliação.

O presente estudo considerou as recomendações sugeridas pela Associação Americana de Endodontistas e pela Academia Americana de Radiologia Oral e Maxilofacial (2011)[2] para a indicação da TCFC no tratamento endodôntico, entre elas o diagnóstico de patologia periapical endodôntica em pacientes que apresentem sinais e sintomas clínicos contraditórios ou não-específicos, que tenham sintomas pobremente localizados associados a um dente não tratado endodonticamente.

Baseado na possibilidade de os profissionais terem imagens de TCFC como auxílio ao diagnóstico, as aplicações da ferramenta de medição da TCFC certamente podem favorecer a obtenção do comprimento do dente. Assim, é possível confirmar esse comprimento usando o localizador apical eletrônico evitando uma nova exposição radiográfica.

7. CONCLUSÃO

A determinação do comprimento de trabalho em imagens de TCFC mostrou ser tão similar quanto às determinações obtidas por meio do método radiográfico e do localizador apical eletrônico.

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In Vivo Comparison of Root Canal Working Length using Cone Beam Computed Tomography, Periapical Radiograph, and Electronic Apex Locator

ANDRÉ LUIZ GOMIDE DE MORAIS, DDS, MSc;
Post-graduate Student, School of Dentistry, Federal University of Goiás, Goiânia, GO, Brazil;

ANA HELENA GONÇALVES DE ALENCAR, DDS, MSc, PhD;
Professor of Endodontics, Federal University of Goiás, Goiânia, GO, Brazil;

DANIEL ALMEIDA DECURCIO, DDS, MSc, PhD;
Professor of Endodontics, Federal University of Goiás, Goiânia, GO, Brazil;

CARLOS ESTRELA, DDS, MSc, PhD;
Chairman and Professor of Endodontics, Federal University of Goiás, Goiânia, GO, Brazil;

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Correspondence and offprint requests:
Professor Carlos ESTRELA
Department of Oral Sciences, Federal University of Goiás
Praça Universitária s/n, Setor Universitário, Goiânia, GO, Brazil
CEP: 74.605-220
E-mail: estrela3@terra.com.br

Abstract

Introduction Strategies to obtain the working length to prepare and fill the root canals has been relevant theme of discussion in endodontics. The purpose of this study was to compare in vivo cone beam computed tomography (CBCT) images working length determination with periapical radiography and electronic apex locator. **Methods** The root canal working lengths of 30 single-rooted teeth from 19 patients whose diagnosis was apical periodontitis were evaluated. Initial periapical radiographs for diagnosis and treatment planning, employing the parallelism technique, were taken. The minor foramen was located using Root ZX® locator by advancing a stainless steel K-file that best suited the root canal, according to the manufacturer´s instructions. The radiographic measurement was made by advancing a stainless steel K-file in the root canal, until its tip was 1.0 mm from the root apex (determined from the measures obtained by the electronic apex locator). CBCT images were acquired with i-CAT system (aiming the diagnoses of cases of apical periodontitis that showed to be complex and doubtful) and measured with specific function of i-CAT software. These 3 working length were tabulated and compared. Kruskal-Wallis test was used to analyze the differences between working lengths methods. The significance was set at $\alpha=5\%$. **Results** The mean values and standard deviations for working length determination by electronic apex locator, periapical radiography and CBCT images were 21.5 ± 3.1, 21.32 ± 3, 21.4 ± 2.7, respectively. Significant differences were not verified statistically ($p>0.05$). **Conclusions** CBCT images working length determination showed to be precise when compared with periapical radiography and electronic apex locator.

Introduction

The anatomical complexity of the apical third of root canals may hamper the endodontic therapy in cases of teeth with apical periodontitis (1). The elimination of micro-organisms depends on the sequence of operative steps, such as coronal access, process of sanitizing of root canal and filling (2). Contemporary endodontics is challenged to a better understanding of variations in the internal anatomy of root canals, strategies for obtaining the working length for the preparation and selection of antimicrobial methods to disrupt the bacterial biofilm (2,3).

The prognosis of endodontic therapy has been influenced by apical limit of root canal instrumentation and obturation. Kojima et al. (4) and Schaeffer et al. (5), from a meta-analysis, discussed the ideal limit for ending the instrumentation and root canal filling. It was determined the influence of this apical limit, of pathological condition of the pulp and of periodontal status in endodontic prognosis. A higher success rate was observed when treatment included the filling limit below radiographic apex.

The radiographic methods represent the preference of most professionals to determine the working length (6-8). Although the technique of parallelism produces minor changes during the production of radiographic imaging, the ideal film and the orientation of the x-ray tube are difficult aspects to standardize. Distorted radiographic images (stretched or shortened) may result from errors in the vertical positioning of the film or from angulation of the radiographic positioner (7,8). Changes in the angle between the radiographic film and the tooth have a significant effect on linear measures based on periapical radiographs (9,10).

Several devices were developed in order to find the most appropriate length for instrumentation and obturation of root canals. The electronic apex locators were thought to reduce the number of radiographs used in endodontic treatment and to minimize the subjectivity involved in radiographic interpretation. The development of new technologies aimed to make endodontic therapy more rational, less stressful for the professional, making it the most accurate (11-18).

Different devices have been devised for this purpose, existing at market several operating principles, such as electronic measurement devices of root canal length based on the resistance, on low-frequency oscillation, high frequency, capacitance and resistance devices, equipment based on voltage gradient, on two frequencies and impedance difference, on two frequencies and impedance ratio and on multifrequency impedance. The current apex locators measure the impedance difference between two frequencies, or the ratio of two electrical impedances. The accuracy of electronic measuring devices has been the subject of numerous studies (11-18). Its function constitutes to find the location of the apical constriction, which represents the transition between the pulp and periodontal tissues, point of reference in which endodontic instrumentation and obturation should terminate preferentially (1,19,20).

New imaging modalities have been included in clinical practice, such as digital radiography, densitometry, computed tomography, magnetic resonance imaging, ultrasound and nuclear techniques (21-26). These detailed images show in a high-resolution the oral structures and allow the early detection of changes in maxillofacial structures. The cone beam computed tomography (CBCT) represents an important technology recently introduced in dentistry, with high potential for clinical application and accuracy compared to periapical radiography. Its contribution to the treatment plan, diagnosis, treatment and prognosis of different diseases, besides its value in research are observed (22-26).

Another important aspect is related to the software that determines linear distances and volumes of anatomical structures, favoring the preoperative planning of maxillofacial injuries, the determination of the marginal bone level viewing the orthodontic treatment, reconstruction techniques, changes in bone level after regenerative periodontal therapy, periodontal defect, periapical lesions, and root resorptions (9,10,21-26).

The null hypothesis of this study is related to the absence of differences between the measure of working length obtained by the CBCT images, periapical radiographs and electronic apex locator. Thus, the purpose of this study was to compare in vivo working length determined by CBCT with that obtained by periapical radiographs and electronic apex locator.

Material and Methods

Patients

This clinical study evaluated the working length of root canals in 30 single-rooted teeth (13 upper central incisors, 14 upper lateral incisors and 3 upper canines). Diagnosis was asymptomatic apical periodontitis associated to primary infection and closed cavity, from 19 patients (12 women and 7 men, mean age, 33.8) from Dental Urgency Service of the School of Dentistry of Federal University of Goiás, Brazil, in 2009 and 2010.

All images and data for analysis in this study were obtained from a database from another study entitled Process of repair of apical periodontitis by densitometric analysis with cone beam computed tomography in function of different therapeutic strategies (UFG, Proc. #171/2009).

CBCT images were obtained in all the patients with the aim of diagnosing the periapical diseases which showed complex or doubtful (as joint position statement of the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology)(27), and for the treatment planning.

This study was approved by the Institutional Ethics in Research Committee of Federal University of Goiás, Goiânia, Brazil. All patients were informed on the study aim and signed an informed consent form.

Determination of the Working Length

Initially, radiographs were obtained of all the teeth for the diagnosis and treatment plan. The technique of parallelism was employed making use of radiographic positioner in order to minimize distortions caused by errors of angles. The study included teeth with: absence of calcifications of the root canals, internal or external resorption and the presence of fully formed root apices.

All periapical radiographs were obtained using Spectro 70X machine (Dabi Atlante, Ribeirão Preto,SP, Brazil), with focal tube of 0.8 mm X 0.8 mm, Kodak Insight E films (Eastman Kodak Co, Rochester , NY, USA). All films were processed in an automatic processor.

The coronary opening was made using diamond burs # 1012 and 2200 (KG Sorensen, Agerskov, Denmark). After opening, the root canals were copiously irrigated with 5 mL of 2.5% hypochlorite sodium solution and its content was aspirated. Then, the coronary chamber was filled by the same solution (2.5% NaOCl) and it was made the exploration and initial emptying of root canal, using a size 15 stainless steel K-file (Dentsply-Maillefer, Ballaigues, Switzerland). The preparation of the entrance orifice and cervical third of the root was made using Gates-Glidden burs # 2 and 3, and Largo burs # 1 and 2.

Only after those, the working length was determined, using an electronic apex locator as follows: the minor foramen was located using Root ZX® locator (J Morita Corp 2004) by advancing a stainless steel K-file that best suited the root canal, according to the manufacturer´s instructions. The clip was applied to the patient´s lip and the file holder was attached to the file. The file was advanced into the canal until the reading on the display flashed "APEX" and the audible continuous signal indicated that the anatomical foramen had been reached. The silicon stopper on the inserted file was then set to an anatomical tooth landmark, the file was retracted and the distance between the stopper and the file tip was measured using a millimeter ruler. After that, the silicon stopper was retreated 1.0 mm and this measurement was noted.

The radiographic measurement was made by advancing a K-file in the root canal, until its tip was 1.0 mm from the root apex (determined from the measures obtained by the electronic apex locator). Radiography was exposed and if the file tip was seen not to be 1.0 mm from the radiographic apex, the file was repositioned and another radiograph taken to ensure that it was in the right measurement (Fig. 1A-C). The distance from the stop to the file tip was noted. This image was obtained by radiographic parallelism technique.

CBCT images acquisition

CBCT images were acquired with i-CAT Cone-Beam 3D imaging system (Imaging Sciences International, Hatfield, PA, USA). Volumes were reconstructed with 0.2 mm isometric voxel. The tube voltage was 120 kVp and the tube current 3.8 mA.

Exposure time was 40 seconds. Images were examined with the scanner's proprietary software (Xoranversion 3.1.62; Xoran Technologies, Ann Arbor, MI, USA) in a PC workstation running Microsoft Windows XP professional SP-2 (Microsoft Corp, Redmond, WA, USA), with Intel(R) Core(TM) 2 Duo-6300 1.86 Ghz processor (Intel Corporation, USA), NVIDIA GeForce 6200 turbo cache graphics card (NVIDIA Corporation, USA) and Monitor EIZO – Flexscan S2000, resolution 1600x1200 pixels (EIZO NANAO Corporation Hakusan, Japan).

Imaging Measurements

The method used to study the root canal working length determination with CBCT was based on delimiting and measuring the distance between anatomical landmarks of the dental crowns and roots (Fig.1D-I). All the measurements on the CBCT images were acquired by a dental radiology specialist, using a proprietary measurement tool supplied with the CBCT scanner (Xoran 3.1.62; Xoran Technologies, Ann Arbor, MI, USA). A specific function of i-CAT software that offers values in millimeters was used to measure teeth images. The measurements were made in the sagittal plane (the reference used was the largest measurement extension given by the software). The reference distance used was maximum width between the incisal edge or cusp tip and the most apical point of the root. The measurement considered was 1.0 mm short of the root apex.

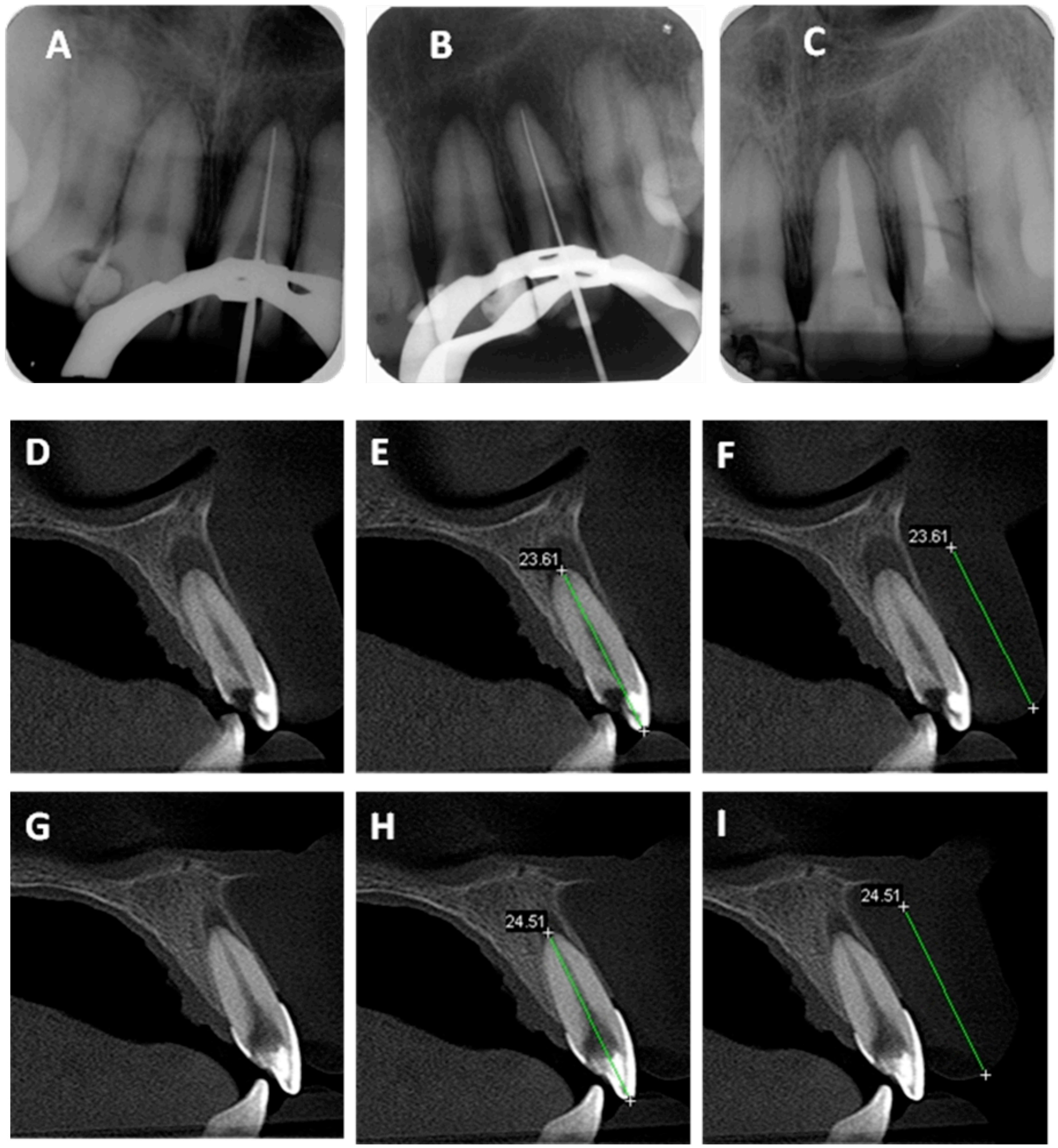

Figure 1. Clinical case to obtain working length of maxillary central and lateral incisors by using periapical radiographs (A-C) and CBCT images (D-I).

Statistical Analysis

Kruskal-Wallis test was used to analyze comparisons between working lengths using CBCT, radiographic imaging measurements and electronic apex locator (SPSS

Statistics for Windows 19.0 - SPSS Inc., Chicago, IL, USA). To determine if the data were non-parametric or not, Levene test was used. The significance was set at α=5%.

Results

The mean values, and standard deviations for determination of working length obtained by electronic apex locator, periapical radiography and CBCT images were described in Table 1. It was not verified significant differences statistically (p>0.05).

Table 1. Average and standard deviations of measurements obtained by electronic apical locator, periapical radiography and CBCT images.

Electronic apical locator	**Periapical radiography**	**CBCT image**	***p***
A ± SD	A ± SD	A ± SD	
21.5 ± 3.1	21.32 ± 3	21.4 ± 2.7	0.95

(A – Average; SD – Standard Deviation)

Discussion

Several factors may be responsible for the success or the failure of endodontic treatment. Etiology of endodontic post-treatment disease has suggested two important factors such as microbial (intraradicular and extraradicular infection – bacteria, fungi) and non-microbial ones (endogenous – true cysts; exogenous – foreign-body reaction)(2). The quality of sanitization process, the 3-dimensional filling, and a good coronal restoration constitute essential elements to success, being that the prognosis might be affected by overfill or significant underfill (2-5,28). Thus, a considerable aspect that requires attention is the choice of the best apical limit to prepare and to fill the root canals (1,4,5,28-30).

Different strategies have been used to determine the position of the apical foramen and thus enable the measurement of working length of root canals (1,11-18). The most widely used method has involved the periapical radiographs. However, although it is accepted that the apical constriction is located on average 0.5 to 1.0 mm from the radiographic apex, there are variations in the relationship from that point of reference which result in errors of instrumentation, and that obviously influence the position of endodontic filling. References of anatomical structures visualized on radiographs can be showed as hidden (1,19,20).

Electronic devices to detect the end of the root canal represent important innovations in endodontic treatment (11,13-18,29,30). The functionality of these equipment's are based on the fact that the electrical conductivity of the tissues surrounding the root apex is greater than the conductivity inside root canal system being the channel dry or filled by non-conductive fluid (11-18,29,30).

The mean values, and standard deviations for determination of working length obtained by electronic apex locator, periapical radiograph and were CBCT images were 21.5 ± 3.1, 21.32 ± 3 e 21.4 ± 2.7, respectively (Table 1). It was not verified significant differences statistically ($p>0.05$). The present study considered the recommendations suggested by the American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology (27) for the use of CBCT in endodontic treatment, such as the diagnosis of dental periapical pathosis in patients who present with contradictory or nonspecific clinical signs and symptoms, who have poorly localized symptoms associated with an endodontically untreated tooth.

The results of the current study are in accordance with previous report which analysis the potential of CBCT in root-length measurements (10,28,31,32). Janner et al. (31) in a pilot investigation evaluated the utility and precision of already existing CBCT scans in measuring the endodontic working length, and compared it with standard clinical procedures. Among three included patients, 9 teeth with a total of 10 root canals were treated. For these root canals, a strong correlation was found between the endodontic working length measured in the CBCT images and the electronic apex locator measurements. Sherrard et al. (10) evaluated the accuracy and reliability of tooth-length and root-length measurements derived from CBCT volumetric data made from 7 fresh porcine heads. CBCT scans are at least as accurate and reliable as periapical radiographs for tooth-length and root-length determinations. Maret et al. (32) verified in tooth germs that volumes obtained with CBCT and micro-CT devices were statistically similar. Geometric deviations between CBCT and micro-CT three-dimensional surface reconstructions did not show any areas of important and systematic errors. Differences between the length of root canal obturation detected by periapical radiography and CBCT images were showed by Moura et al. (28). Periapical radiographs showed that root canal obturations were 1–2 mm short of the apex in 88%, 89.3%, and 95% of the anterior teeth, premolars, and molars, respectively. CBCT images showed obturations had the same length in 70%, 73.7%, and 79% of anterior teeth, premolars, and molars, respectively. The frequency of AP was significantly greater in molars than in the other tooth groups, regardless of diagnostic method.

Despite of benefits and limitations of periapical radiograph were well-known (21-26,30), and to represent the device common used for regulating root canal working length, several professionals have chosen the electronic apex locator. In vivo studies have been discussed its performance (30,33,34). Willians et al. (30) compared the difference between the in vivo working length established by viewing a periapical radiograph and the in vitro measurement from the file tip to the apical foramen of the extracted tooth. Radiographs are a useful adjunct in establishment of an appropriate working length; however, two trends should be considered. When a file is long radiographically it is actually longer than it appears by an average of 1.2 mm. When a file is short radiographically it is closer to the apical foramen than it appears by an average of 0.46 mm. Shabahang et al. (33) verified that the Root ZX® was able to locate the foramen in 25 teeth with a clinical accuracy rate of 96.2%. Ravanshad et al. (34) compared the effect of working length determination using electronic apex locator or radiograph on the length adequacy of final working length as well as the final obturation in a total of 84 patients. The endodontic treatment using the electronic apex locator is quite comparable, if not superior, to radiographic length measurement regarding the rates of acceptable and short cases.

Some clinical conditions may influence on adequate performance of the electronic equipment, determining care and limitations. Intact vital tissue, inflammatory exudate and blood can conduct electrical current and cause inaccurate readings, so that the presence of these factors should be minimized before accepting apex readings. Other conductors that may cause a short-circuiting are metallic restorations, caries, saliva and instruments in a secondary channel. The accumulation of dentine debris and calcifications can also affect the accurate working length determination with electronic apex locators (11-18,29,30,33,34).

The influence of the apical limits determination for root canal preparation and obturation on outcome of root canal treatment, and the available resources to evaluate correctly the root canal working length have been subject for constant discussions (1,4,5,20,28). The criteria for successful root canal treatment should be reviewed based on the results achieved with new technologies such as CBCT (25,26,35). Periapical radiography has been employed to assess the working length as well as the outcome of root canal treatment. Interesting considerations were made by Wu et al. (35) about the limitations of previously published systematic reviews evaluating the outcome of root canal treatment. The absence of a periapical radiolucency have been considered a confirmation of a healthy periapex. However, a high percentage of cases confirmed as healthy by radiographs revealed apical periodontitis on CBCT and by histology. The serious limitations of longitudinal clinical studies restrict the correct interpretation of root canal treatment outcomes. The outcomes of root canal treatment should be re-evaluated in long-term longitudinal studies using CBCT and stricter evaluation criteria.

Based on the possibility of professionals have CBCT images such as aid to diagnosis, the applications of measurement tool of CBCT certainly may favor tooth length achievement. Thus, it is possible to confirm this length by using electronic apex locator avoiding a new radiographic exposure.

Conclusions

The determination of the working length of root canal using CBCT images showed to be precise when compared to radiographic method and eletronic apex locator.

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ANEXOS

1 - NORMAS DE PUBLICAÇÃO DO JOURNAL OF ENDODONTICS

Guidelines for Publishing Papers in the JOE

Writing an effective article is a challenging assignment. The following guidelines are provided to assist authors in submitting manuscripts.

The *JOE* publishes original and review articles related to the scientific and applied aspects of endodontics. Moreover, the *JOE* has a diverse readership that includes full-time clinicians, full-time academicians, residents, students and scientists. Effective communication with this diverse readership requires careful attention to writing style.

General Points on Composition

Authors are strongly encouraged to analyze their final draft with both software (e.g., spelling and grammar programs) and colleagues who have expertise in English grammar. References listed at the end of this section provide a more extensive review of rules of English grammar and guidelines for writing a scientific article. Always remember that clarity is the most important feature of scientific writing. Scientific articles must be clear and precise in their content and concise in their delivery since their purpose is to inform the reader. The Editor reserves the right to edit all manuscripts or to reject those manuscripts that lack clarity or precision, or have unacceptable grammar. The following list represents common errors in manuscripts submitted to the *JOE*:

a. The paragraph is the ideal unit of organization. Paragraphs typically start with an introductory sentence that is followed by sentences that describe additional detail or examples. The last sentence of the paragraph provides conclusions and forms a transition to the next paragraph. Common problems include one-sentence paragraphs, sentences that do not developthe theme of the paragraph (see also section "c", below), or sentences with little to no transition within a paragraph.

b. Keep to the point. The subject of the sentence should support the subject of the paragraph. For example, the introduction of authors' names in a sentence changes the subject and lengthens the text. In a paragraph on sodium hypochlorite, the sentence, "In 1983, Langeland et al., reported that sodium hypochlorite acts as a lubricating factor during instrumentation and helps to flush debris from the root canals" can be edited to: "Sodium hypochlorite acts as a lubricant during instrumentation and as a vehicle for flushing the generated debris (Langeland et al., 1983)". In this example, the paragraph's subject is sodium hypochlorite and sentences should focus on this subject.

c. Sentences are stronger when written in the active voice, i.e., the subject performs the action. Passive sentences are identified by the use of passive verbs such as "was," "were," "could," etc. For example: "Dexamethasone was found in this study to be a factor that was associated with reduced inflammation", can be edited to: "Our results demonstrated that dexamethasone reduced inflammation". Sentences written in a direct and active voice are generally more powerful and shorter than sentences written in the passive voice.

d. Reduce verbiage. Short sentences are easier to understand. The inclusion of unnecessary words is often associated with the use of a passive voice, a lack of focus or run-on sentences. This is not to imply that all sentences need be short or even the same length. Indeed, variation in sentence structure and length often helps to maintain reader interest. However, make all words count. A more formal way of stating this point is that the use of subordinate clauses adds variety and information when constructing a paragraph.(This section was written deliberately with sentences of varying length to illustrate this point.)

e. Use parallel construction to express related ideas. For example, the sentence, "Formerly, Endodontics was taught by hand instrumentation, while now rotary instrumentation is the common method", can be edited to "Formerly, Endodontics was taught using hand instrumentation; now it is commonly taught using rotary instrumentation". The use of parallel construction in sentences simply means that similar ideas are expressed in similar ways, and this helps the reader recognize that the ideas are related.

f. Keep modifying phrases close to the word that they modify. This is a common problem in complex sentences that may confuse the reader. For example, the statement, “Accordingly, when conclusions are drawn from the results of this study, caution must be used”, can be edited to “Caution must be used when conclusions are drawn from the results of this study”.

g. To summarize these points, effective sentences are clear and precise, and often are short, simple and focused on one key point that supports the paragraph’s theme.

General Points on the Organization of Original Research Manuscripts

a. **Please Note**: *Starting in 2009, all abstracts should be organized into sections that start with a one-word title (in bold), i.e., Introduction, Methods, Results, Conclusions, etc., and should not exceed more than 250 words in length.*
b. **Title Page**: The title should describe the major conclusion of the paper. It should be as short as possible without loss of clarity. Remember that the title is your advertising billboard–it represents your major opportunity to solicit readers to spend the time to read your paper. It is best not to use abbreviations in the title since this may lead to imprecise coding by electronic citation programs such as PubMed (e.g., use “sodium hypochlorite” rather than NaOCl). The author list must conform to published standards on authorship (see authorship criteria in the Uniform Requirements for Manuscripts Submitted to Biomedical Journals at ***www.icmje.org***).
c. **Abstract**: The abstract should concisely describe the purpose of the study, the hypothesis, methods, major findings and conclusions. The abstract should describe the new contributions made by this study. The word limitations (250 words) and the wide distribution of the abstract (e.g., PubMed) make this section challenging to write clearly. This section often is written last by many authors since they can draw on the rest of the manuscript. Write the abstract in past tense since the study has been completed. Three to ten keywords should be listed below the abstract.
d. **Introduction**: The introduction should briefly review the pertinent literature in order to identify the gap in knowledge that the study is intended to address. The purpose of the study, the tested hypothesis and its scope should be described. Authors should realize that this section of the paper is their primary opportunity to establish communication with the diverse readership of the *JOE*. Readers who are not expert in the topic of the manuscript are likely to skip the paper if the introduction fails to provide sufficient detail. However, many successful manuscripts require no more than a few paragraphs to accomplish these goals.
e. **Material and Methods**: The objective of the methods section is to permit other investigators to repeat your experiments. The three components to this section are the experimental design, the procedures employed, and the statistical tests used to analyze the results. The vast majority of manuscripts should cite prior studies using similar methods and succinctly describe the particular aspects used in the present study. The inclusion of a “methods figure” will be rejected unless the procedure is novel and requires an illustration for comprehension. If the method is novel, then the authors should carefully describe the method and include validation experiments. If the study utilized a commercial product, the manuscript should state that they either followed manufacturer’s protocol or specify any changes made to the protocol. Studies on humans should conform to the Helsinki Declaration of 1975 and state that the institutional IRB approved the protocol and that informed consent was obtained. Studies involving animals should state that the institutional animal care and use committee approved the protocol. The statistical analysis section should describe which tests were used to analyze which dependent measures; p-values should be specified. Additional details may include randomization scheme, stratification (if any), power analysis, drop-outs from clinical trials, etc.
f. **Results**: Only experimental results are appropriate in this section (i.e., neither methods nor conclusions should be in this section). Include only those data that are critical for the study. Do not include all available data without justification, any repetitive findings will be rejected from publication. All Figs./Charts/Tables should be described in their order of numbering with a brief description of the major findings.

Figures: There are two general types of figures. The first type of figure includes photographs, radiographs or micrographs. Include only essential figures, and even if essential, the use of composite figures containing several panels of photographs is encouraged. For example, most photo-, radio- or micrographs take up one column-width, or about 185 mm wide X 185 mm tall. If instead, you construct a two columns-width figure (i.e., about 175 mm wide X 125 mm high when published in the *JOE*), you would be able to place about 12 panels of photomicrographs (or radiographs, etc.) as an array of four columns across and three rows down (with each panel about 40 X 40 mm). This will require some editing on your part given the small size of each panel, you will only be able to illustrate the most important feature of each photomicrograph. Remember that each panel must be clearly identified with a letter (e.g., "A", "B", etc.), in order for the reader to understand each individual panel. Several nice examples of composite figures are seen in recent articles by Chang, et al, (*JOE* 28:90, 2002), Hayashi, et al, (*JOE* 28:120, 2002) and by Davis, et al (JOE 28:464, 2002). At the Editor's discretion, color figures may be published at no cost to the authors. However, the Editor is limited by a yearly allowance and this offer does not include printing of reprints.

<u>The second type of figure</u> are graphs (i.e., line drawings) that plot a dependent measure (on the Y axis) as a function of an independent measure (usually plotted on the X axis). Examples include a graph depicting pain scores over time, etc. Graphs should be used when the overall trend of the results are more important than the exact numerical values of the results. For example, a graph is a convenient way of reporting that an ibuprofen treated group reported less pain than a placebo group over the first 24 hours, but was the same as the placebo group for the next 96 hours. In this case, the trend of the results is the primary finding; the actual pain scores are not as critical as the relative differences between the NSAID and placebo groups.

Tables: Tables are appropriate when it is critical to present exact numerical values. However, not all results need be placed in either a table or figure. For example, the following table may not necessary:

% NaOCl	N/Group	% Inhibition of Growth
0.001	5	0
0.003	5	0
0.01	5	0
0.03	5	0
0.1	5	100
0.3	5	100
1	5	100
3	5	100

Instead, the results could simply state that there was no inhibition of growth from 0.001-0.03% NaOCl, and a 100% inhibition of growth from 0.03-3% NaOCl (N=5/group). Similarly, if the results are not significant, then it is probably not necessary to include the results in either a table or as a figure. These and many other suggestions on figure and table construction are described in additional detail in Day (1998).

f. **Discussion**: The conclusion section should describe the major findings of the study. Both the strength and weaknesses of the observations should be discussed. What are the major conclusions of the study? How does the data support these conclusions? How do these findings compare to the published literature? What are the clinical implications? Although this last section might be tentative given the nature of a particular study, the authors should realize that even preliminary clinical implications might have value for the clinical readership. Ideally, a review of the potential clinical significance is the last section of the discussion.
g. **References**: The reference style follows Index Medicus and can be efficiently learned from reading past issues of the *JOE*. Citations are placed in parentheses at the end of a sentence or at the end of a clause that requires a literature citation. Do not use superscript for references. Original reports are limited to 35 references. There are no limits in the number of references for review articles.

4. Page Limitations for Manuscripts in the Category of Basic Science/Endodontic Techniques

a. **What is the limitation?** Original research reports in the category of basic science/endodontic techniques are limited to no more than 2,000 words (total for the abstract, introduction, methods, results and conclusions), and a total of three Figs./Charts/Tables. If a composite figure is used (as described above), then this will count as two of the three permitted Figs./Charts/Tables.
b. **Does this apply to me?** Manuscripts submitted to the *JOE* can be broadly divided into several categories including review articles, clinical trials (e.g., prospective or retrospective studies on patients or patient records, or research on biopsies excluding the use of human teeth for technique studies), basic science/biology (animal or culture studies on biological research related to endodontics, or relevant pathology or physiology), and basic science/techniques (e.g., stress/strain/compression/strength/failure/composition studies on endodontic instruments or materials). Manuscripts submitted in this last category are the only category subject to these limitations. If you are not

sure whether your manuscript falls within this category please contact the Editor by e-mail at *jendodontics@uthscsa.edu*.

c. **Why page limitations?** Most surveyed stakeholders of the *JOE* desire timely publication of submitted manuscripts and an extension of papers to include review articles and other features. To accomplish these goals, we must reduce the average length of manuscripts since increasing the *JOE*'s number of published pages is prohibitively expensive. Although a difficult decision, restricting this one category of manuscripts accomplishes nearly all of these goals since ~40-50% of published papers are in this category.

d. **How do I make my manuscript fit these limitations?** Adhering to the general writing methods described in these guidelines (and in the resources listed below) will help to reduce the size of the manuscript. Authors are encouraged to focus on only the essential aspects of the study and to avoid inclusion of extraneous text and figures. The Editor will reject manuscripts that exceed these limitations.

5. Available Resources:

. Strunk W, White EB. The Elements of Style. Allyn & Bacon, 4th ed, 2000, ISBN 020530902X

a. Day R.. How to Write and Publish a Scientific Paper. Oryx Press, 5th ed. 1998. ISBN 1-57356-164-9

b. Woods G. English Grammar for Dummies. Hungry Minds:NY, 2001 (an entertaining review of grammar)

c. Alley M. The Craft of Scientific Writing. Springer, 3rd edition 1996 SBN 0-387-94766-3.

d. Alley M. The Craft of Editing. Springer, 2000 SBN 0-387-98964-1.

2 – PARECER CONSUBSTANCIADO DO COMITÊ DE ÉTICA EM PESQUISA (UFG)

SERVIÇO PÚBLICO FEDERAL

UNIVERSIDADE FEDERAL DE GOIÁS
PRÓ-REITORIA DE PESQUISA E PÓS-GRADUAÇÃO
COMITÊ DE ÉTICA EM PESQUISA

UFG

PROTOCOLO
171/2009

Goiânia, 23 de novembro de 2009

PARECER CONSUBSTANCIADO

I. IDENTIFICAÇÃO:

Título do projeto: "Processo de reparo da periodontite apical por analise densitométrica com tomografia computodorizada Cone Beam em função de estratégias terapêuticas diferentes" .

Pesquisador Responsável: Carlos Estrela

Pesquisador Participante: Ana Helena G. de Alencar, Cyntia Rodrigues de A. Estrela, Daniel de Almeida Decurcio, Julio Almeida Silva.

Local de realização: FO/UFG

Informamos que o Comitê de Ética em Pesquisa da Universidade Federal de Goiás, após análise das adequações solicitadas, **Aprovou,** o projeto acima referido, e o mesmo foi considerado em acordo com os princípios éticos vigentes.

O pesquisador responsável deverá encaminhar ao CEP/UFG, relatórios da pesquisa, encerramento, conclusão (ões) e publicação (ões) de acordo com as recomendações da Resolução 196/96.

Prof. João Teodoro Pádua
Pró-Reitor em exercício
Pró-Reitoria de Pesquisa e Pós- Graduação

Profa Dra Rita Goreti Amaral
Coordenadora do CEP/UFG

3 – CARTA DE DECLARAÇÃO DE CONFORMIDADE / JOURNAL OF ENDODONTICS.

Journal of Endodontics

Copyright Transfer/IRB Approval/HIPAA Compliance Statement

Carlos Estrela ("Author") has submitted an originally authored article ("Article") entitled: **"In Vivo Comparison of Root Canal Working Length using Cone Beam Computed Tomography, Periapical Radiograph, and Electronic Apex Locator"** to Journal of Endodontics for publication which is published by Elsevier, Inc. ("Publisher"). In exchange for publication of the Article, Author represents and warrants to the Journal and the Publisher, together with their officers and directors, that the Article delivered for publication is original and does not infringe the patent, trademark, copyright, trade secret rights or other proprietary rights of third parties ("IP Rights"). Author also represents that, except as indicated below, Author has no financial interest or arrangement with any entity which interest or arrangement might be perceived to bear on the objectivity of the Article, unless that financial interest or arrangement has been disclosed in writing to the Journal. Author further represents that the Article was created in compliance with the provisions of the Health Insurance Portability and Accountability Act (HIPAA) of 1996, and the Article contains no "protected health information" as that term is defined by HIPAA.

Author further represents that the study was performed in compliance with Author's institution's appropriate policies related to the use of animal and/or human subjects and human-derived material (the "IRB").

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I am the responsible author signing on behalf of all co-authors of the manuscript.

Corresponding Author: Carlos Estrela

Signature ______________________

Date January 31, 2012

4 – CONFIRMAÇÃO DE SUBMISSÃO DO ARTIGO AO JOURNAL OF ENDODONTICS.

Dear Dr. Estrela,

Your submission entitled "In Vivo Comparison of Root Canal Working Length using Cone Beam Computed Tomography, Periapical Radiography, and Electronic Apex Locator" has been received by the Journal of Endodontics.

You will be able to check on the progress of your paper by logging on to the Journal of Endodontics web site as an author.

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Kind regards,

Journal of Endodontics