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**CAMPUS I – CAMPINA GRANDE**  
**PRÓ-REITORIA DE PÓS-GRADUAÇÃO E PESQUISA**  
**DEPARTAMENTO DE ODONTOLOGIA**  
**PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA**  
**CURSO DE DOUTORADO EM ODONTOLOGIA**

**COMPARAÇÃO DA ACURÁCIA DA TOMOGRAFIA COMPUTADORIZADA DE  
FEIXE CÔNICO E RADIOGRAFIA PERIAPICAL DIGITAL NA DETECÇÃO DE  
INSTRUMENTOS ENDODÔNTICOS FRATURADOS EM MOLARES  
MANDIBULARES: UM ESTUDO *EX VIVO***

**DIEGO FILIPE BEZERRA SILVA**

**CAMPINA GRANDE**

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Tese apresentada ao Programa de Pós-Graduação em Odontologia da Universidade Estadual da Paraíba, como parte dos requisitos para obtenção do título de Doutor em Odontologia.

**Área de concentração:** Estudo das Alterações do Sistema Estomatognático

**ORIENTADORA: PROFA. DRA. DANIELA PITA DE MELO**

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*"A felicidade não é um lugar onde se chega; ela está no que se vive durante o caminho percorrido..."*  
**Lavínia Lins**

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## AGRADECIMENTOS

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*“As pessoas nunca acham que você está naquele extremo e vai chegar ao outro. Só que eu costumo dizer que tudo que a gente quer na nossa vida só depende da gente. É a força do que você quer fazer pra você.”*

Anitta

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*...And just like that, after a long wait, a day like any else,  
I decided to triumph, to look for the opportunities, not to wait.  
I decided to see every problem as the opportunity to find a solution.  
I decided to see every desert as the opportunity to find an oasis.  
I decided to see every night as a mystery to solve.  
I decided to see every day as a new opportunity to be happy.  
That day I found that my only enemies were my own weaknesses,  
That day I lost the fear of losing and I started to fear not winning,  
I discovered that I was not the best and maybe never have been.  
I stopped caring about who was the winner and who was the loser.  
Now I care only about knowing more than yesterday.  
I learned that the hard thing is to stop climbing to the top, instead of not reaching it.  
I learned that the best triumph that I can have is to have the right of calling someone “my  
friend”.  
I discovered that love is more than a feeling of being in love, “love is a philosophy of life”.  
That day I stopped being a reflection of the few triumphs in my past and I started to be my  
own tenuous light of the present;  
I learned that it does not matter if you are alight... if you are not going to illuminate  
another’s road.  
That day I decided to change so many things...  
That day I learned that dreams only exist to be made to come true  
Since that day I don’t sleep to rest...  
Now, I dream just for dreams.*

**Walt Disney**



RESUMO

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## RESUMO

Este trabalho teve como objetivo comparar a precisão da tomografia computadorizada de feixe cônico (TCFC) e a radiografia periapical digital (RPD) na detecção de instrumentos endodônticos fraturados em canais radiculares totalmente obturados de molares mandibulares. O segundo objetivo foi avaliar o impacto de diferentes miliamperagens (mA) na detecção de instrumentos endodônticos fraturados em TCFC. Quarenta e dois dentes foram obturados, e três tipos de instrumentos endodônticos (WaveOne® Gold; Reciproc® Blue; Protaper® Next), fraturados em 2 e 3 mm, foram inseridos nos canais mesiovestibulares de 30 dentes da amostra. Para aquisição dos volumes de TCFC, foi usado o *scanner* KAVO OP 3D PRO. As imagens foram adquiridas utilizando os parâmetros fixos de campo de visão de 5 cm × 5 cm, 90 kVp, 85 µm voxel e tempo de exposição de 8,7 s, com quatro variações de mA (6,3 mA, 7,1 mA, 8,0 mA e 9,0 mA). Para a aquisição das imagens de RPD, foi utilizado o aparelho Focus Xray, ajustado para 70 kVp, 7 mA e tempo de exposição de 0,06 segundos e o sensor RVG 5200 tamanho 2. As imagens de RPD foram adquiridas em três planos horizontais diferentes (ortorradiar; mesiorradial e distorradiar). Todas as imagens foram avaliadas por três especialistas em radiologia oral e maxilofacial quanto à presença ou ausência de instrumento endodôntico fraturado, em uma escala de cinco pontos. Para TCFC, foi usado o teste ANOVA multi-way com testes post-hoc de Tukey, enquanto que para RPD, foi usada a ANOVA two-way. Para comparar o desempenho dos métodos de imagem, foi usada uma ANOVA one way com testes post-hoc de Tukey. O nível de significância foi definido em 5% ( $p = 0,05$ ). No artigo 1, em relação à comparação do desempenho da RPD e TCFC, foi observada diferença estatisticamente significativa para o instrumento Protaper® Next ( $p < 0,05$ ), com pior valor de área sob a curva ROC (Az) para TCFC. No artigo 2, na avaliação da TCFC, a Az na detecção do instrumento WaveOne® Gold, no tamanho de 3 mm, foi significativamente maior do que os outros instrumentos avaliados, em todas as mA avaliadas ( $p < 0,05$ ). Concluiu-se que, o método diagnóstico mais indicado na detecção de instrumentos endodônticos fraturados é a RPD. Com relação à TCFC, a variação na corrente do tubo não impactou a visualização do instrumento endodôntico fraturado.

**Palavras-chave:** tomografia computadorizada de feixe cônico; radiografia dentária digital; endodontia; tratamento do canal radicular; preparo de canal radicular.

## ABSTRACT

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## ABSTRACT

The main objective of this study was to compare cone-beam computed tomography (CBCT) and digital periapical radiography in the detection of separated endodontic instruments (SI) in fully filled root canals of mandibular molars. The second objective was to evaluate the impact of different milliamperages (mA) on the detection of SI in CBCT. Forty-two teeth were obturated, and 2 and 3 mm SI of three types of endodontic instruments (WaveOne® Gold; Reciproc® Blue; Protaper® Next) were inserted into the mesiobuccal canals of 30 of the test teeth. The KAVO OP 3D PRO scanner was used to acquire CBCT examinations. Images were acquired using fixed parameters of a field of view of 5 cm × 5 cm, 90 kVp, 85 µm voxel, and an exposure time of 8.7 s, and varying the mA from 6.3 mA to 9.0 mA. To acquire the digital periapical radiography images, the Focus Xray device was used, adjusted to 70 kVp, 7 mA and exposure time of 0.06 seconds, and the RVG 5200 sensor, size 2. RPD images were acquired in three different horizontal planes (orthoradial; mesioradial and distoradial, both with a 30° angle). All images were evaluated by three experts for the presence or absence of a SI, on a five-point scale. For CBCT, the multi-way ANOVA test with Tukey post-hoc tests was used, while for digital periapical radiography, the two-way ANOVA was used. To compare the performance of the imaging methods, a one-way ANOVA with Tukey post-hoc tests was used. The significance level was set at 5% ( $p = 0.05$ ). In article 1, regarding the comparison of the performance of digital periapical radiography and CBCT, a statistically significant difference was observed for the Protaper® Next instrument ( $p < 0.05$ ), with a worse area under the ROC curve (Az) value for CBCT. In article 2, in the CBCT evaluation, the Az in the detection of the WaveOne® Gold SI 3 mm size, was significantly higher than the other instruments evaluated, in all mA evaluated ( $p < 0.05$ ). It was concluded that the most indicated diagnostic method for detecting fractured endodontic instruments is digital periapical radiography. Regarding CBCT, the variation in the tube current did not impact the visualization of the SI.

**Keywords:** cone-beam computed tomography; radiography, dental, digital; endodontics; root canal therapy; root canal preparation.

## LISTA DE ILUSTRAÇÕES

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## LISTA DE ILUSTRAÇÕES

|                                                                                                                                                                                                               | <b>Página</b> |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| <b>Figura 1.</b> Representação esquemática da curva de tensão e deformação mostrando a transformação cristalográfica de acordo com a tensão induzida. ....                                                    | 36            |
| <b>Figura 2.</b> Recipientes utilizados para armazenamento da amostra. ....                                                                                                                                   | 48            |
| <b>Figura 3.</b> (A) Finalização do seccionamento da coroa dentária, perpendicularmente ao longo eixo do dente. (B) Refinamento do preparo. (C) Aspecto final do dente preparado para ser instrumentado. .... | 49            |
| <b>Figura 4.</b> Motor endodôntico utilizado para o preparo dos condutos radiculares. ....                                                                                                                    | 49            |
| <b>Figura 5.</b> (A) Exploração e (B) medição do comprimento dos canais radiculares. ....                                                                                                                     | 50            |
| <b>Figura 6.</b> (A) Delimitação do comprimento do fragmento a ser cortado. (B) Fragmento do instrumento endodôntico após o corte. ....                                                                       | 51            |
| <b>Figura 7.</b> (A) Demarcação da guta-percha 3 mm aquém do limite apical. (B) Aquecimento da guta-percha na lamparina à álcool. (C) Fixação do instrumento fraturado na guta-percha. ....                   | 52            |
| <b>Figura 8.</b> (A) Mandíbula recoberta por cera rosa nº7 utilizada para aquisição das imagens. (B) Dente da amostra posicionado no alvéolo da mandíbula para posterior aquisição de imagens. ....           | 53            |
| <b>Figura 9.</b> Aparelho Focus Xray. ....                                                                                                                                                                    | 53            |
| <b>Figura 10.</b> (A, B, C). Imagens adquiridas de um dente sem a presença de instrumento fraturado. (D, E, F). Imagens adquiridas de um dente com a presença de instrumento fraturado. ....                  | 54            |
| <b>Figura 11.</b> Aparelho 3 em 1 KAVO OP 3D PRO utilizado na pesquisa. ....                                                                                                                                  | 55            |
| <b>Figura 12.</b> Interface do programa após realização da TCFC. ....                                                                                                                                         | 55            |

## LISTA DE ABREVIATURAS E SIGLAS

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## LISTA DE ABREVIATURAS E SIGLAS

- **CCD** Do inglês *charge-coupled device*, traduzido como dispositivo de carga acoplada.
- **CCTS** Centro de ciências, tecnologia e saúde.
- **CM** Do inglês *controlled memory*, traduzido como memória controlada.
- **CMOS** Do inglês *complementary metal–oxide–semiconductor*, traduzido como semicondutor de óxido metálico complementar.
- **DICOM** Do inglês *Digital Imaging and Communications in Medicine*, traduzido como Imagens Digitais e Comunicações em Medicina.
- **EDTA** Do inglês *Ethylenediaminetetraacetic acid*, traduzido como ácido etileno diamino tetracético.
- **FMEL** *Fine medium* extra longo.
- **kVp** Do inglês *kilovoltage peak*, traduzido como quilovoltagem pico.
- **mA** Miliampère.
- **NiTi** Níquel-titânio.
- **nm** Nanometro.
- **PSP** Do inglês *photostimulable phosphor plate*, traduzido como placa de fósforo fotoestimulável.
- **RPD** Radiografia periapical digital.
- **SPSS** Do inglês *Statistical Package for the Social Sciences*, traduzido como Pacote de Serviço Estatístico para as Ciências Sociais.
- **TCFC** Tomografia computadorizada de feixe cônico.
- **TCLE** Termo de consentimento livre e esclarecido.
- **TIFF** Do inglês *Tagged Image File Format*.
- **UEPB** Universidade Estadual da Paraíba.



## LISTA DE QUADROS

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## LISTA DE QUADROS

|                                                                                                                     | Página |
|---------------------------------------------------------------------------------------------------------------------|--------|
| <b>Quadro 1.</b> Ligas de NiTi usada para a fabricação de instrumentos endodônticos. ....                           | 32     |
| <b>Quadro 2.</b> Descrição das variáveis que foram estudadas na pesquisa executada. ....                            | 45     |
| <b>Quadro 3.</b> Grupos de estudo, de acordo com a presença de material obturador e/ ou instrumento fraturado. .... | 47     |

## SUMÁRIO

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## SUMÁRIO

|                |                                                                            |           |
|----------------|----------------------------------------------------------------------------|-----------|
| <b>1</b>       | <b>CONSIDERAÇÕES INICIAIS.....</b>                                         | <b>29</b> |
| 1.1            | Anatomia dos canais radiculares.....                                       | 30        |
| 1.2            | Tratamento endodôntico.....                                                | 31        |
| <b>1.2.1</b>   | <b>Instrumentos mecanizados utilizados na endodontia.....</b>              | <b>31</b> |
| <i>1.2.1.1</i> | <i>Limas endodônticas Reciproc Blue, WaveOne Gold e ProTaper Next.....</i> | <i>34</i> |
| 1.3            | Fraturas de instrumentos endodônticos.....                                 | 35        |
| 1.4            | Métodos de identificação de instrumentos fraturados.....                   | 38        |
| <b>2</b>       | <b>OBJETIVOS.....</b>                                                      | <b>42</b> |
| 2.1            | Objetivo geral.....                                                        | 42        |
| 2.2            | Objetivos específicos.....                                                 | 42        |
| <b>3</b>       | <b>METODOLOGIA.....</b>                                                    | <b>44</b> |
| 3.1            | Aspectos éticos.....                                                       | 44        |
| 3.2            | Tipo de estudo.....                                                        | 44        |
| 3.3            | Local do estudo.....                                                       | 44        |
| 3.4            | População.....                                                             | 45        |
| 3.5            | Amostra.....                                                               | 45        |
| <b>3.5.1</b>   | <b>Critérios de inclusão.....</b>                                          | <b>45</b> |
| <b>3.5.2</b>   | <b>Critérios de exclusão.....</b>                                          | <b>45</b> |
| 3.6            | Variáveis estudadas.....                                                   | 45        |
| 3.7            | Coleta de dados.....                                                       | 46        |
| <b>3.7.1</b>   | <b>Caracterização da amostra.....</b>                                      | <b>47</b> |
| <b>3.7.2</b>   | <b>Preparo da amostra.....</b>                                             | <b>48</b> |
| <i>3.7.2.1</i> | <i>Preparo dos canais radiculares.....</i>                                 | <i>49</i> |
| <i>3.7.2.2</i> | <i>Fratura dos instrumentos e obturação dos canais radiculares.....</i>    | <i>51</i> |
| <b>3.7.3</b>   | <b>Preparo da mandíbula.....</b>                                           | <b>53</b> |
| <b>3.7.4</b>   | <b>Aquisição das imagens radiográficas.....</b>                            | <b>53</b> |
| <b>3.7.5</b>   | <b>Aquisição das imagens tomográficas.....</b>                             | <b>54</b> |
| <b>3.7.6</b>   | <b>Avaliação das imagens radiográficas e dos volumes gerados.....</b>      | <b>56</b> |
| <b>3.7.7</b>   | <b>Treinamento e calibração.....</b>                                       | <b>56</b> |
| 3.8            | Análise estatística.....                                                   | 56        |
| <b>4</b>       | <b>ARTIGOS.....</b>                                                        | <b>59</b> |

|     |                                                                                                                                                                             |     |
|-----|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| 4.1 | <b>Apresentação.....</b>                                                                                                                                                    | 59  |
| 4.2 | <b>Primeiro Artigo a Ser Submetido.....</b>                                                                                                                                 | 60  |
| 4.3 | <b>Segundo Artigo a Ser Submetido.....</b>                                                                                                                                  | 81  |
| 5   | <b>CONSIDERAÇÕES FINAIS.....</b>                                                                                                                                            | 97  |
|     | <b>REFERÊNCIAS.....</b>                                                                                                                                                     | 99  |
|     | <b>APÊNDICE A – TERMO DE DOAÇÃO DOS DENTES.....</b>                                                                                                                         | 105 |
|     | <b>APÊNDICE B – DECLARAÇÃO DE EMPRÉSTIMO DA<br/>MANDÍBULA SECA.....</b>                                                                                                     | 106 |
|     | <b>APÊNDICE C – PLANILHA COM PREENCHIMENTO DAS<br/>VARIÁVEIS INCLUÍDAS DAS AQUISIÇÕES FEITAS COM TCFC. ....</b>                                                             | 107 |
|     | <b>APÊNDICE D - PLANILHA COM PREENCHIMENTO DAS<br/>VARIÁVEIS INCLUÍDAS DAS AQUISIÇÕES FEITAS COM OS<br/>APARELHOS E SENSORES DE RADIOGRAFIA PERIAPICAL<br/>DIGITAL.....</b> | 108 |
|     | <b>ANEXO A – PARECER DO COMITÊ DE ÉTICA EM PESQUISA<br/>DA UEPB.....</b>                                                                                                    | 110 |
|     | <b>ANEXO B – NORMAS PARA SUBMISSÃO DE ARTIGOS NO<br/>PERIÓDICO <i>CLINICAL ORAL INVESTIGATIONS</i>.....</b>                                                                 | 114 |
|     | <b>ANEXO C – NORMAS PARA SUBMISSÃO DE ARTIGOS NO<br/>PERIÓDICO <i>JOURNAL OF ENDODONTICS</i>.....</b>                                                                       | 137 |

## CONSIDERAÇÕES INICIAIS

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## 1 CONSIDERAÇÕES INICIAIS

A fratura de instrumentos manuais ou mecanizados dentro dos canais radiculares pode ocorrer durante a etapa do preparo químico-mecânico de um tratamento endodôntico. Na ocorrência de fratura, é necessário que o cirurgião-dentista tome a decisão quanto a escolha do melhor procedimento a ser aplicado, pois a partir deste, será determinada a forma de conclusão do tratamento, seja com a remoção do fragmento ou a permanência intracanal do mesmo (Özer *et al.* 2017; Kirchhof *et al.* 2018; Koç *et al.* 2018; Costa *et al.* 2020). A remoção do fragmento é preferencialmente a primeira escolha de tratamento, porém, em muitos casos, esta remoção é difícil e requer mais experiência e conhecimento técnico por parte do profissional. Quando essa habilidade é limitada, a remoção pode provocar iatrogenias, como perfurações do canal ou formação de degraus (Özer *et al.* 2017; Kirchhof *et al.* 2018; Koç *et al.* 2018; Costa *et al.* 2020).

A decisão para o planejamento do tratamento da fratura do instrumento deve ser baseada em um diagnóstico preciso, que é assegurado principalmente por exames de imagem como radiografias periapicais ou tomografia computadorizada de feixe cônico (TCFC). No entanto, algumas limitações dos métodos de imagem, bi ou tridimensionais, podem dificultar a identificação do instrumento fraturado. Dependendo do tipo e tamanho do instrumento fraturado, além dos materiais utilizados para obturação dos condutos radiculares, a mudança de parâmetro de exposição ou até mesmo o método de imagem pode melhorar na identificação do instrumento fraturado.

Dessa forma, a execução deste estudo tornou-se necessária, pois foram utilizadas a TCFC e da radiografia periapical digital (RPD), com diferentes parâmetros de exposição, diferentes tipos e comprimentos de instrumentos de níquel-titânio (NiTi), e seus resultados contribuirão para que o clínico tenha segurança ao escolher o melhor método de imagem para identificação de possíveis instrumentos fraturados nos canais radiculares. Ademais, os resultados desta pesquisa poderão auxiliar nas seleções e aplicações dos melhores parâmetros de exposição para aumentar a acurácia da detecção do instrumento fraturado.

Devido à complexidade da anatomia dos canais radiculares nos dentes molares inferiores, os métodos de tratamento térmico para desenvolvimentos das limas endodônticas, diferentes possibilidades de fratura dos instrumentos, e aos dois métodos de imagem utilizados neste estudo, este capítulo foi subdividido em seções.

## 1.1 Anatomia dos canais radiculares

O tratamento de todo o sistema de canais radiculares é essencial para maximizar a possibilidade de obter bom resultado na terapia endodôntica (Reyhani; Rahimi; Shahi, 2007). Para se ter sucesso no tratamento endodôntico é necessário um conhecimento significativo das características anatômicas das raízes e do sistema de canais radiculares (Razumova *et al.*, 2018). O canal radicular começa a partir do orifício na câmara pulpar e termina apicalmente com um orifício aberto no periodonto (Razumova *et al.*, 2019).

O primeiro molar mandibular é o primeiro dente posterior que erupciona e o que frequentemente requer tratamento endodôntico (Reyhani; Rahimi; Shahi, 2007; Ballullaya; Vemuri; Kumar, 2013; Razumova *et al.*, 2019). Geralmente esse dente possui duas raízes separadas, uma mesial e uma distal, e ocasionalmente, tem três raízes. A raiz distal é frequentemente reta (Razumova *et al.*, 2019), com canal único, normalmente reto até o ápice, sendo oval ou achatado, em seção transversal, mas bastante largo, o que facilita a instrumentação. Frequentemente, os 1-2 mm mais apicais desse canal se curvam até 90 graus distalmente, mas isso raramente é um problema clínico (Ballullaya; Vemuri; Kumar, 2013).

A raiz mesial é caracterizada por uma superfície mesiodistal achatada e uma superfície vestibulo-lingual alargada, apresentando dois canais que, em 90% dos casos, permanecem separados até o forame; nos 10% restantes, eles se unem em um forame comum (Ballullaya; Vemuri; Kumar, 2013). O canal méso-vestibular possui seu trajeto tortuoso (Gulabivala; Ng, 2014) e, conseqüentemente mais propenso à fratura de instrumentos endodônticos. Da perspectiva proximal, esse canal curva-se primeiro para vestibular e depois para lingual. Já no canal méso-lingual, sua porção coronal é mais reta e, em seguida, curva-se vestibularmente no terço médio da raiz (Gulabivala; Ng, 2014).

O segundo molar mandibular é semelhante ao primeiro molar mandibular. Apesar de sua semelhança, é um pouco menor coronalmente e tende a ser mais simétrico (Gutmann; Fan, 2021). Geralmente tem duas raízes, uma mesial e outra distal, embora possa ter uma ou três raízes (Razumova *et al.*, 2019). As duas raízes geralmente seguem distalmente em uma curva gradual, com os ápices próximos um do outro, possuindo sulco oclusal +4 e quatro cúspides semelhantes (Gutmann; Fan, 2021). A cavidade de acesso para um segundo molar de dois canais é retangular, larga no sentido méso-distal e estreita no sentido vestibulo-lingual (Gutmann; Fan, 2021). A raiz mesial geralmente possui dois canais que tendem a se fundir no terço apical para dar origem a um forame apical comum (Watson, 2010).



## 1.2 Tratamento endodôntico

O dano pulpar pode ser causado por diversos fatores como: trauma, em casos de fratura, luxação ou hábitos parafuncionais (como o bruxismo); iatrogenia, nos casos de movimentação ortodôntica excessiva e clareamento dental; idiopática, como reabsorção; e bacteriana, principalmente no caso de cárie (Pražmo; Godlewska; Mielczarek, 2017). Esses fatores podem causar danos irreversíveis à polpa dentária, necessitando, assim, de um tratamento adequado dos canais radiculares.

A base da terapia endodôntica consiste em tratar os dentes comprometidos por patologias pulpares e periapicais, de modo que o paciente possa recuperar sua estética e função. Essa terapia constitui-se em uma sequência de procedimentos que normalmente incluem quatro fases: instrumentação ou preparação mecânica, irrigação, medicação intracanal e obturação (Pinheiro *et al.*, 2020).

Para o preparo satisfatório do canal radicular são necessários instrumentos que penetrem em seu interior e, com auxílio de soluções irrigadoras corretas, promovem sua limpeza. Atualmente, os instrumentos manuais tradicionais, feitos de aço inoxidável, coexistem com instrumentos mais flexíveis, feitos de ligas de NiTi, que permitem sua utilização em equipamentos que possibilitam uma instrumentação mecanizada (Pinheiro *et al.*, 2020).

Em revisão sistemática que comparou a instrumentação manual com pelo menos um instrumento mecanizado no preparo do canal radicular de dentes humanos permanentes, observou-se que os instrumentos mecanizados causaram uma redução significativa no tempo de instrumentação e uma menor alteração da curvatura do canal radicular. Ademais, a instrumentação mecanizada apresentou melhores resultados quanto ao seu manuseio no canal radicular, capacidade de centralização dentro do trajeto do canal e modelagem do conduto radicular. Por outro lado, a instrumentação manual teve melhor desempenho em relação à formação de *smear layer* e permitiu que as superfícies do canal radicular ficassem mais instrumentadas com menos defeitos de dentina (Peralta-Mamani *et al.*, 2019).

### 1.2.1 Instrumentos mecanizados utilizados na endodontia

A história da Endodontia é marcada por duas eras, divididas entre si pela introdução da liga NiTi como o material mais elegível para a fabricação de instrumentos endodônticos mecanizados. Sua implementação, de fato, mudou os procedimentos de instrumentação dos

sistemas de canais radiculares, passando a ser considerada uma revolução tecnológica que estabeleceu o início da endodontia moderna (Zanza *et al.*, 2021).

A liga equiatômica de NiTi contém números semelhantes de átomos de níquel e titânio (55% de níquel e 45% de titânio) e pode existir em três fases microestruturais: austenita, martensita e a fase R. A liga de NiTi da fase R é flexível, já no estado austênico é relativamente rígida e possui memória de forma, enquanto que na fase martensítica é flexível e dúctil e pode ser facilmente deformada (Liang; Yue, 2022). O sucesso da liga de NiTi reside em suas propriedades biológicas e mecânicas como biocompatibilidade (Speck; Fraker, 1980), resistência à corrosão (Buehler; Wang, 1968; Pedullà *et al.*, 2013), efeito de memória de forma e superelasticidade (Zanza *et al.*, 2021).

O efeito de memória de forma e a superelasticidade têm um papel fundamental na determinação do comportamento mecânico dos instrumentos de NiTi. O efeito de memória de forma, permite que os instrumentos de NiTi “memorizem” uma determinada forma e retornem, por aquecimento, à sua forma original, graças à transição entre duas fases microestruturais: a fase martensítica, que é estável abaixo de uma determinada temperatura, e a fase austenítica, que é estável acima dessa temperatura. A superelasticidade permite que a liga de NiTi, quando sob estresse mecânico, seja deformada reversivelmente pela criação de uma fase induzida por tensão, chamada de martensita induzida por tensão (Zanza *et al.*, 2021).

Ao longo dos anos, os fabricantes dos instrumentos endodônticos propuseram diferentes tratamentos térmicos, com o objetivo de torná-los com desempenho mecânico cada vez melhor (QUADRO 1) (Zupanc; Vahdat-Pajouh; Schäfer, 2018; Zanza *et al.*, 2021).

**Quadro 1.** Ligas de NiTi usada para a fabricação de instrumentos endodônticos.

| <b>Liga</b>                   | <b>Fase Microestrutural</b> | <b>Sistema NiTi</b>                                                                            |
|-------------------------------|-----------------------------|------------------------------------------------------------------------------------------------|
| <i>Liga convencional NiTi</i> | Austenítica                 | Mtwo, OneShape, ProFile, ProTaper Universal, RaCe, BioRaCe, iRace F360, F6 Skytaper, EdgeTaper |
| <i>fase-R</i>                 | Austenítica                 | Twisted File, Twisted File Adaptive, K3XF (não torcido)                                        |

|                                  |                                                                          |                                                                       |
|----------------------------------|--------------------------------------------------------------------------|-----------------------------------------------------------------------|
| <i>M-Wire</i>                    | Austenítica com pequenas quantidades de fase R e martensita              | ProFile Vortex, ProFile GT Series X, ProTaper Next, Reciproc, WaveOne |
| <i>CM Wire</i>                   | Martensítica com quantidades variadas de austenita e fase R              | Hyflex CM, THYPOON, Infinite Flex NiTi Files, V-Taper 2H, Hyflex EDM  |
| <i>Ouro tratado termicamente</i> | Martensítica com quantidades variadas de austenita e fase R              | ProTaper Gold, WaveOne Gold                                           |
| <i>Azul tratado termicamente</i> | Martensítica com quantidades variadas de austenita e fase R              | ProFile Vortex Blue, Reciproc Blue, Rotate                            |
| <i>MaxWire</i>                   | Martensítica (20°C), austenítico (35°C)                                  | XP-endo Finisher, XP-endo Shaper                                      |
| <i>T-Wire</i>                    | Martensítico com quantidades variadas de austenita e fase R              | 2Shape                                                                |
| <i>C-Wire</i>                    | Martensítica com quantidades variadas de austenita e fase R              | OneCurve, RECI One                                                    |
| <i>FireWire</i>                  | Martensítica com quantidades variadas de austenita e fase R              | EdgeOne Fire, EdgeSequel Sapphire, EdgeTaper Platinum, EdgeFile X7    |
| <i>AF-R Wire</i>                 | Martensítica com quantidades variadas de austenita e fase R              | AF-One                                                                |
| <i>Tratamento térmico FKG</i>    | Transição de fase variando de 32°C a 35°C (entre martensita e austenita) | R-Motion file System, Race Evo                                        |

**Fonte:** Adaptação de Zanza *et al.* (2021).

### 1.2.1.1 Limas Endodônticas Reciproc® Blue, WaveOne® Gold e ProTaper® Next

A liga CM (*controlled memory*) - *Wire* sofre repetidos tratamentos de calor e resfriamento para formar uma camada de óxido de titânio, e a cor da superfície da liga varia de acordo com a espessura da camada de óxido de titânio (Liang; Yue, 2022). Quando a espessura é entre 60 a 80 nm, a cor da superfície é azul, chamada de fio CM-Blue; quando a espessura é entre 100 a 140 nm, a cor da superfície é dourada, denominada de fio CM-Gold (Shen *et al.*, 2016). A camada de óxido de titânio formada compensa a perda de dureza durante o processamento da liga e aumenta a eficiência de corte e resistência ao desgaste (Plotino *et al.*, 2014).

O instrumento WaveOne® Gold (Dentsply Sirona, Carolina do Norte, EUA), composto pelo fio CM-Gold, incorpora um paralelogramo com duas arestas de corte e recurso de *design* descentralizado (Özyürek, 2016). Esse instrumento é produzido usando o processamento térmico obtido aquecendo o instrumento de NiTi e depois resfriando-o lentamente (Webber, 2015). O instrumento Reciproc® Blue (VDW GmbH, München, Alemanha), composto pelo fio CM-Blue, é o resultado de um processamento térmico que, segundo o fabricante, melhora a flexibilidade e resistência à fadiga cíclica, e reduz os valores de microdureza superficial em comparação com os instrumentos de uma edição anterior do sistema Reciproc® NiTi (De Deus *et al.*, 2017).

Em estudo experimental com objetivo de comparar as topografias de superfície e os perfis em nanoescala de instrumentos mecanizados WaveOne®, WaveOne® Gold, Reciproc® e Reciproc® Blue intactos e usados, antes e depois do preparo de quatro canais curvos, cada, observou-se que houveram diferenças significativas. Os instrumentos intactos WaveOne® e WaveOne® Gold apresentaram os maiores valores, seguidos pelos instrumentos Reciproc® e Reciproc® Blue ( $P < 0,05$ ). Além disso, os instrumentos WaveOne®, Reciproc® e Reciproc® Blue usados exibiram rachaduras e microcavidades. Os instrumentos WaveOne® Gold e Reciproc® Blue apresentaram níveis significativamente mais altos de distorção da superfície após a instrumentação do canal radicular, e o WaveOne® exibiu o menor nível de deformação da superfície (Alrahabi; Atta, 2019).

Em 2007, a Tulsa Dental lançou um novo tipo de liga de NiTi, a *M-wire*, desenvolvida após o tratamento térmico de uma liga de NiTi austenítica convencional. Os instrumentos de NiTi compostos de ligas *M-wire*, como o sistema ProTaper® Next e o sistema ProFile® Vortex, têm maior flexibilidade, resistência à fadiga e resistência à fratura. Comparado com a liga de NiTi convencional, o instrumento *M-wire* tem melhor capacidade de posicionamento cêntrico,

pode manter melhor a forma original do canal radicular curvo e pode reduzir o desvio do canal radicular (Liang; Yue, 2022).

O instrumento endodôntico rotatório ProTaper® Next (Dentsply Maillefer, Ballaigues, Suíça) foi projetado para seguir passivamente o canal radicular até atingir o comprimento de trabalho (Fernández-Pazos *et al.*, 2018). Esses instrumentos possuem seção transversal retangular e movimento rotacional assimétrico contínuo que, segundo o fabricante, ao reduzir os pontos de contato com as paredes do canal, reduz a fadiga cíclica do instrumento (Conceição, Ferreira; Braga; Pina-Vaz, 2020).

No estudo de Elnaghy e Elsaka (2014), com objetivo de comparar a resistência à torção, flexibilidade e microdureza superficial das limas ProTaper® Next com Twisted Files e RaCe, observou-se que a ProTaper® Next apresentou a maior resistência à torção e microdureza, seguida pela RaCe ( $P < 0,05$ ). As seções transversais de fratura de todas as marcas mostraram ondulações perto do centro da superfície de fratura. Além disso, a classificação nos valores de resistência à flexão foi: RaCe > ProTaper® Next > Twisted Files.

Devido às vantagens oferecidas pelos instrumentos mecanizados de NiTi, estudos anteriores com questionários mostram que aproximadamente 50% a 80% dos cirurgiões-dentistas, generalistas ou especialistas, utilizam esses instrumentos na sua prática clínica (Madarati; Watts; Qualtrough, 2008a; Madarati; Watts; Qualtrough, 2008b; Koch *et al.*, 2009; Mozayeni; Golshah; Nik Kerdar, 2011). No caso de retratamento endodôntico, observou-se que aproximadamente 39,6% dos cirurgiões-dentistas usaram instrumentos mecanizados e manuais, enquanto 22,5% deles usaram apenas instrumentos mecanizados (Azees, 2021).

### 1.3 Fraturas de instrumentos endodônticos

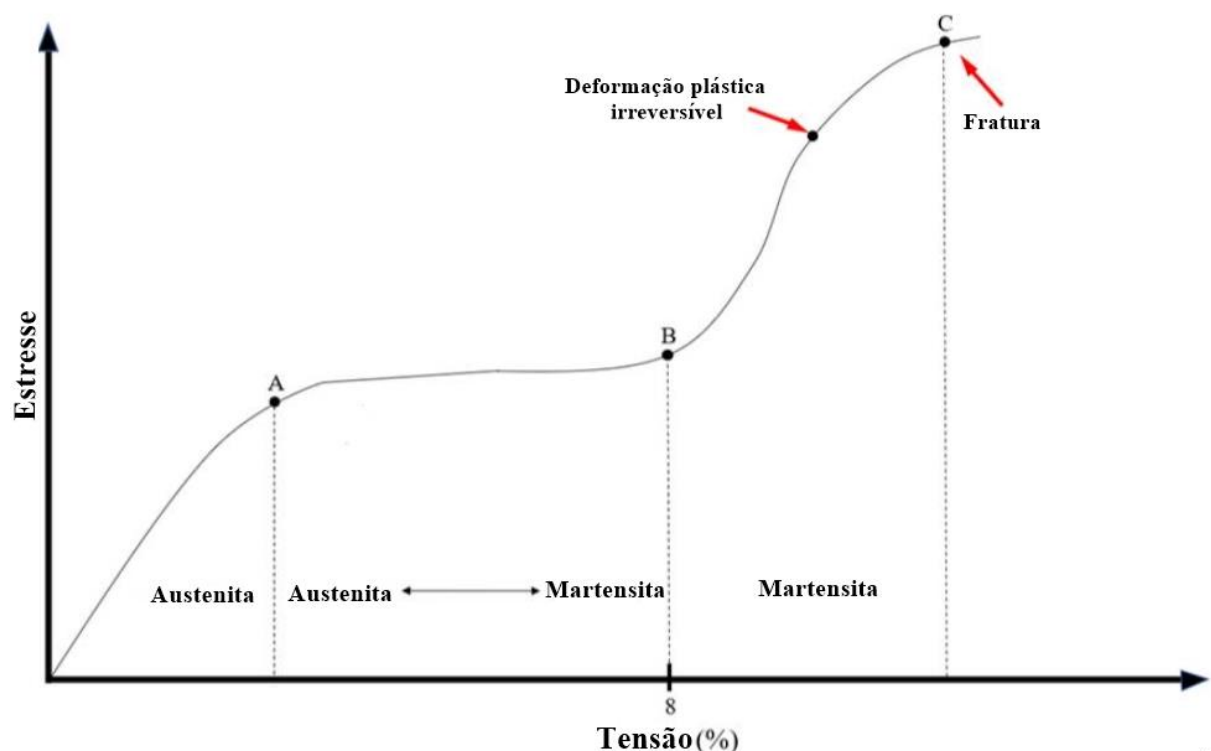
Apesar das características dos instrumentos de NiTi, como memória de forma e a superelasticidade, vários fatores podem contribuir para sua fratura, como anatomia dos canais radiculares, frequência de uso, alta velocidade e torque de rotação (Madarati; Watts; Qualtrough, 2008c; Malarvizhi *et al.*, 2020). Vários tipos de instrumentos endodônticos (limas manuais ou mecanizadas, brocas Gates Glidden) e diferentes materiais (NiTi, aço inoxidável) podem sofrer fratura. Quando ocorre, é uma situação frustrante para o clínico, pois pode impedir o acesso ao ápice e, na maioria das vezes, impedir a instrumentação completa e a obturação do canal radicular (Vouzara; Chares; Lyroudia, 2018).

As respostas mecânicas da liga de NiTi sob determinada carga são representadas por meio da Figura 1. A curva de tensão e deformação pode ser dividida por três linhas verticais

(A, B e C na Figura 1) que individualizam no gráfico três áreas diferentes de acordo com a organização microestrutural da liga de NiTi: a região austenítica, na qual a liga é composta por austenita; a região austenítica/martensítica (também chamada de fase R), na qual ocorre uma transformação parcial da austenita em martensita, de acordo com a aplicação da tensão; a região da martensita, na qual a quantidade total de austenita é transformada em martensita acima de certas cargas (Thompson, 2000; Zhou; Peng; Zheng, 2013).

Abaixo de certa carga, a transformação induzida pelo estresse mecânico é totalmente reversível (deformação elástica) como consequência direta da superelasticidade, porém se um limite de escoamento for excedido, a deformação se torna irreversível (deformação plástica) e o instrumento endodôntico é danificado permanentemente (Hamilton *et al.*, 2004). Os instrumentos endodônticos de NiTi, quando submetidos à tensões que ultrapassam os limites de elasticidade do material, sofrem transformações plásticas e depois fraturam, caso a tensão não seja removida (Zanza *et al.*, 2021).

**Figura 1.** Representação esquemática da curva de tensão e deformação mostrando a transformação cristalográfica de acordo com a tensão induzida.



**Fonte:** Adaptação de Zanza *et al.* (2021).

Os instrumentos mecanizados de NiTi fraturados são classificados naqueles que falham como resultado de fadiga de flexão cíclica, nos que sofrem falha de torção ou uma combinação

de ambos (Pessoa; Silva; Gavini, 2013). A fratura por torção ocorre quando o instrumento (geralmente a ponta) fica travado no canal enquanto a haste da lima continua a girar (Mcguigan; Louca; Duncan, 2013).

A fratura por fadiga flexural ocorre quando o instrumento não se prende, mas gira livremente em uma curvatura, gerando ciclos de tensão/ compressão no ponto de máxima flexão até ocorrer a fratura (Pessoa; da Silva; Gavini, 2013), que ocorre essencialmente devido ao uso excessivo da liga metálica. Outros fatores potencialmente contribuintes para a fadiga do metal incluem corrosão e alterações causadas por expansão e contração térmica (Mcguigan; Louca; Duncan, 2013). Diferentemente da fratura por torção, a fratura flexural não apresenta deformação prévia, critério utilizado por muitos profissionais para descartar os instrumentos. Assim, há muita dúvida sobre os principais fatores responsáveis pela fratura flexural para estabelecer o protocolo correto para prevenir sua ocorrência (Pessoa; da Silva; Gavini, 2013).

A prevalência de instrumentos de NiTi fraturados varia de 1,33% a 1,68% (Iqbal; Kohli; Kim, 2006; Fu; Zhang; Hou, 2011). No estudo retrospectivo de Iqbal, Kohlo e Kim (2006), com 4.865 casos de tratamentos endodônticos, as chances para fratura de instrumentos mecanizados foram sete vezes maiores do que para o instrumento manual. A probabilidade de fraturar uma lima no terço apical foi 33, e 6 vezes mais provável quando comparada aos terços coronal e médio dos canais. De forma semelhante, no estudo retrospectivo de Fu, Zhang e Hou (2011), com 1.367 pacientes (2.180 casos endodônticos, 4.897 canais radiculares), a prevalência de instrumentos fraturados no terço apical (52,5%) foi significativamente maior quando comparado aos terços coronal (12,5%) e médio (27,5%) dos canais.

Com relação aos dentes mais acometidos, Iqbal, Kohlo e Kim (2006) observaram que a maior porcentagem de fraturas dos instrumentos ocorreu nos molares mandibulares (55,5%) e maxilares (33,3%). Além disso, as chances de fraturar um instrumento em molares foram 2,9 vezes maiores do que em pré-molares. Em consonância com esses achados, no estudo de Al-Nazhan, Al-Attas e Al-Maflehi (2018), os instrumentos fraturados foram mais encontrados nos molares mandibulares (52,4%), sendo mais observados no canal vestibular dos pré-molares maxilares e canais méso-vestibulares dos molares mandibulares e maxilares.

No estudo de Caballero-Flores *et al.* (2019), com objetivo de avaliar a incidência de fratura de instrumentos de sistemas reciprocantes de uso único quando usados por estudantes de um programa de pós-graduação em endodontia, a maior taxa de fratura foi de 52,6% na raiz méso-vestibular dos molares mandibulares. Ademais, a incidência de fratura dos instrumentos em relação ao número de canais radiculares foi de 0,92%, sendo o canal méso-vestibular dos molares mandibulares o de maior incidência (53%). O risco de fratura de instrumentos em

molares mandibulares foi cinco vezes maior do que em molares maxilares ( $p = 0,001$ ), enquanto esse risco foi duas vezes mais provável de ocorrer no canal radicular méso-vestibular do que em outros canais radiculares de molares mandibulares ( $p = 0,004$ ).

Nenhuma instrução oficialmente aprovada sobre o tratamento de fratura de instrumentos foi promulgada até o momento (Vouzara; Chares; Lyroudia, 2018). O manejo de um instrumento fraturado pode ser conservador e/ ou cirúrgico. Existem três abordagens principais para o tratamento conservador: a) *bypass* do instrumento fraturado; b) remoção desse instrumento fraturado; c) instrumentação e obturação do canal radicular coronalmente ao fragmento (Madarati; Hunter; Dummer, 2013). Uma das formas de remoção dos instrumentos fraturados é com a utilização de ultrassom (Tordai *et al.*, 2018). Sugere-se também que o paciente seja informado sobre a fratura do instrumento, o tratamento a ser seguido e o prognóstico do dente (Cohen; Schwartz, 1987).

#### 1.4 Métodos de identificação de instrumentos fraturados

O manejo bem-sucedido de problemas endodônticos depende de técnicas de diagnóstico por imagem para fornecer informações sobre os dentes sob investigação e sua anatomia circundante. Desde a sua criação, a radiografia convencional tem permanecido o pilar da imagem em Endodontia (Durack; Patel, 2012). Embora a radiografia periapical e panorâmica produzam detalhes aceitáveis na direção mesiodistal, a observação de detalhes na dimensão vestibulo-lingual é inadequada (Tsurumachi; Honda, 2007), pelo fato de produzir uma imagem bidimensional de uma estrutura tridimensional (Ramos Brito *et al.*, 2017).

Para minimizar essa desvantagem, filtros de imagem podem ser empregados para realçar o fragmento do instrumento no canal radicular. Alguns ajustes simples de brilho, nitidez e contraste podem ser aplicados para melhorar a visualização das estruturas. Além disso, para facilitar a visualização das raízes de dentes multirradiculares que aparecem sobrepostas devido à natureza bidimensional da imagem, técnicas de localização radiográfica como a técnica de Clark podem ser utilizadas (Rosen *et al.*, 2016).

Recentemente, as imagens radiográficas digitais têm sido adotadas como uma alternativa às radiografias convencionais que utilizam filmes radiográficos como meio de captura de imagens. As imagens digitais são capturadas por dois tipos de receptores: sensores sólidos, como os *charge-coupled device* (CCD) ou *complementary metal-oxide-semiconductor* (CMOS), e placas de fósforo, como as *photostimulable phosphor plate* (PSP) (Zhang *et al.*, 2019; Nikkerdar *et al.*, 2020).



Os sistemas digitais apresentam diversas vantagens sobre os sistemas convencionais, como maior qualidade da imagem, rapidez na aquisição, eliminação da etapa do processamento químico, redução da poluição ambiental, menor dose de radiação necessária, e a capacidade de reutilização. No entanto, diferentemente dos sistemas convencionais, os sistemas digitais não podem ser esterilizados, sendo necessário o uso de barreiras de proteção microbiológica (Zhang *et al.*, 2019; Nikkerdar *et al.*, 2020).

A aquisição da imagem através de sensor sólido é praticamente instantânea, utilizando um cabo para transferir o sinal captado para o monitor do computador. No entanto, uma desvantagem é a rigidez do sensor, o que dificulta seu posicionamento intraoral, podendo causar desconforto ao paciente e sendo incompatível com a maioria dos posicionadores radiográficos disponíveis comercialmente (Zhang *et al.*, 2019; Nikkerdar *et al.*, 2020).

Quando pretende-se ter uma visualização mais abrangente da anatomia das estruturas de interesse, é recomendado o uso da TCFC, que produz imagens tridimensionais. Além disso, as fatias dos dados volumétricos produzidos podem ser escolhidas pelo clínico e visualizadas em todos os planos ortogonais e em planos não ortogonais (Durack; Patel, 2012). A TCFC pode ser capaz de diferenciar os instrumentos fraturados devido aos *voxels* isotrópicos elevados de quilovoltagem pico (kVp) e miliampère (mA) das imagens tomográficas, em que é possível reconstruir imagens em qualquer plano (axial, sagital e coronal) com alta fidelidade (Baratto-Filho *et al.*, 2020).

Uma limitação dos sistemas da TCFC é a formação de artefatos (KOÇ *et al.*, 2018). Quando a região de interesse contém objetos metálicos (restaurações, implantes, instrumentos endodônticos) ou obturações do canal radicular, o alto número atômico e a densidade desses materiais levam à geração dos artefatos, que são estruturas vistas na imagem reconstruída, mas que não estão presentes no objeto real (Vasconcelos *et al.*, 2017; Freitas *et al.*, 2018). Esses artefatos comprometem a acurácia da TCFC, pois podem levar à formação de estrias brancas e áreas escuras ao redor de estruturas anatômicas de interesse, dificultando ou mesmo impossibilitando o diagnóstico (Freitas *et al.*, 2018, Koç *et al.*, 2018).

Para melhorar a qualidade da imagem e corrigir defeitos devido a artefatos, alguns sistemas de TCFC fornecem uma ferramenta de redução de artefatos metálicos, para diminuir a variabilidade dos valores de cinza e aumentar a relação contraste-ruído na imagem (Queiroz *et al.*, 2017). Dessa forma, Koç *et al.* (2019) avaliaram a influência da ferramenta de redução de artefatos metálicos na detecção dos instrumentos, porém tendo como conclusões que a aplicação de redução de artefatos para detecção de complicações endodônticas não é recomendada como ferramenta de rotina.

Poucos estudos avaliaram a precisão da TCFC na detecção de limas fraturadas em canais radiculares (D'Addazio *et al.*, 2011; Rosen *et al.*, 2016; Ramos Brito *et al.*, 2017; Koç *et al.*, 2018; Ayatollahi *et al.*, 2019; Fatemeh *et al.*, 2019; Abdinian *et al.*, 2020; Alemam *et al.*, 2020; Baratto-Filho *et al.*, 2020; Madian *et al.*, 2023). Os resultados mostraram que a radiografia periapical tende a ter uma melhor acurácia do que a TCFC na detecção dos instrumentos fraturados. Apesar de que, em estudos como o de Baratto-Filho *et al.* (2020), de 24 canais obturados com o instrumento fraturado, apenas nove instrumentos foram identificados na radiografia periapical digital (37,5%) e nenhum nos volumes de TCFC ( $p > 0,05$ ).

No estudo de Rosen *et al.* 2016, foram avaliadas as imagens de TCFC em comparação com radiografias periapicais e observou-se que instrumentos fraturados não identificados nas imagens de TCFC, foram detectados nas imagens periapicais com sensibilidade de 71,3% e especificidade de 93,8%.

Mais recentemente, no estudo de Madian *et al.* (2023), com objetivo de comparar a eficácia da radiografia periapical e da TCFC sem e com algoritmo de redução de artefatos metálico na detecção de instrumentos endodônticos fraturados em canais radiculares não obturados e obturados, retos e curvos, os valores de sensibilidade e especificidade (0,903) e o índice de Youden (0,89) foram todos mais elevados para a radiografia periapical do que para ambos os exames de TCFC.

Apesar de haver melhores resultados para a radiografia periapical, os estudos publicados não avaliaram os dentes com todos os condutos obturados, o que se assemelha a uma situação clínica. Além disso, geralmente, para a TCFC é usado apenas um parâmetro de exposição. Além disso, este estudo avaliou tamanhos e tipos de instrumentos fraturados. Então, este trabalho pode contribuir para que o clínico tenha segurança ao escolher o melhor método de imagem para identificação de possíveis instrumentos fraturados nos canais radiculares. Ademais, poderá auxiliar nas seleções e aplicações dos melhores parâmetros de exposição para aumentar a acurácia na detecção do instrumento fraturado.

## OBJETIVOS

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## **2 OBJETIVOS**

### **2.1 Objetivo geral**

Comparar a precisão da TCFC e da radiografia periapical digital na identificação de instrumentos endodônticos fraturados em canais radiculares obturados de primeiros e segundos molares mandibulares.

### **2.2 Objetivos específicos**

- Verificar a influência da mA da TCFC na detecção de instrumentos mecanizados fraturados;
- Avaliar a influência do tipo do instrumento, dentro do conduto radicular, na sua detecção, em TCFC e radiografia periapical digital;
- Analisar a influência do tamanho do instrumento fraturado (2 e 3 mm) na sua detecção, utilizando TCFC e radiografia periapical digital.

## METODOLOGIA

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### 3 METODOLOGIA

#### 3.1 Aspectos éticos

O presente estudo foi cadastrado na Base de Registros de Pesquisa envolvendo Seres Humanos (Plataforma Brasil), respeitando a resolução 466/12 e nº 510/2016 do Conselho Nacional de Saúde/ Ministério da Saúde, e submetido à análise de seu conteúdo pelo Comitê de Ética em Pesquisa da Universidade Estadual da Paraíba (UEPB). O projeto foi aprovado sob o parecer nº. 6.026.095 (CAAE: 68420423.4.0000.5187) (ANEXO A). Destaca-se, ainda, que a pesquisa esteve em conformidade com a Declaração de Helsinque.

Para aquisição da amostra, foi feito um pedido de doação de dentes provenientes de exodontias, em que foi solicitada a assinatura do termo de doação de dentes por uma cirurgiã-dentista (APÊNDICE A). Como não foi possível identificar os indivíduos doadores dos dentes, não foi aplicado termo de consentimento livre e esclarecido (TCLE). Além disso, foi solicitada autorização e assinatura do Termo de retirada para utilização da mandíbula humana seca do Laboratório de Morfofisiologia do curso de Odontologia da UEPB, Campus VIII, ao diretor do Centro de Ciências, Tecnologia e Saúde (CCTS) da UEPB (APÊNDICE B).

#### 3.2 Tipo de estudo

A pesquisa desenvolvida consistiu em um estudo do tipo experimental, laboratorial *ex vivo*.

#### 3.3 Local do estudo

A seleção e preparo das amostras foram realizados no Laboratório de Dentística, Prótese Dentária e Endodontia da Universidade Estadual da Paraíba (UEPB), Campus I. A aquisição das imagens periapicais digitais e tomográficas foi realizada no setor de Radiologia do Departamento de Odontologia da instituição referida anteriormente.

### 3.4 População

A população objeto do presente estudo foi constituída por dentes molares mandibulares provenientes de exodontias, dos quais foram realizados tratamento endodôntico com instalação de limas fraturadas e aquisição de imagens radiográficas periapicais digitais e tomográficas.

### 3.5 Amostra

A amostra do estudo foi do tipo não-probabilística, por conveniência, constituída por 42 dentes molares mandibulares.

#### 3.5.1 Critérios de inclusão

Foram incluídos primeiros e segundos molares mandibulares com as raízes completamente formadas, sem a presença de raízes fusionadas, supranumerárias, sem curvatura apical excessiva, sem cáries radiculares e com três canais radiculares.

#### 3.5.2 Critérios de exclusão

Foram excluídos da amostra os dentes com tratamento endodôntico prévio, presença de nódulos pulpare, perfuração ou sinais visíveis de fratura radicular.

### 3.6 Variáveis estudadas

A descrição das variáveis que foram estudadas está descrita no quadro 2.

**Quadro 2.** Descrição das variáveis que foram estudadas na pesquisa executada.

| Variável                               | Definição                                          | Classificação quanto ao plano de análise | Classificação quanto à natureza | Forma de mensuração                                                                   |
|----------------------------------------|----------------------------------------------------|------------------------------------------|---------------------------------|---------------------------------------------------------------------------------------|
| Tipo de instrumento endodôntico (lima) | Instrumento destinado ao alisamento, retificação e | Independente                             | Qualitativa nominal             | Reciproc <sup>®</sup> Blue<br>WaveOne <sup>®</sup> Gold<br>ProTaper <sup>®</sup> Next |

|                                        |                                                                                                                                                      |              |                       |                                                                                                                                         |
|----------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|-----------------------|-----------------------------------------------------------------------------------------------------------------------------------------|
|                                        | alargamento dos canais radiculares                                                                                                                   |              |                       |                                                                                                                                         |
| Instrumentos endodôntico fraturado     | Fratura que ocorre após utilização do instrumento dentro dos canais radiculares ou, em situações laboratoriais, com ponta diamantada em alta rotação | Dependente   | Qualitativa nominal   | 2 mm<br>3 mm                                                                                                                            |
| Método de aquisição das imagens        | Processo de captura e digitalização de imagens a partir da utilização de aparelhos de imagem.                                                        | Dependente   | Qualitativa nominal   | TCFC<br>RPD                                                                                                                             |
| Miliamperagem                          | Responsável pela corrente do tubo (quantidade de radiação)                                                                                           | Independente | Quantitativa contínua | 6.3 mA<br>7.1 mA<br>8.0 mA<br>9.0 mA                                                                                                    |
| Identificação do instrumento fraturado | Método de identificação visual dos instrumentos nas imagens adquiridas                                                                               | Dependente   | Qualitativa nominal   | 1 (definitivamente ausente)<br>2 (provavelmente ausente)<br>3 (incerteza)<br>4 (provavelmente presente)<br>5 (definitivamente presente) |

**Fonte:** Elaborado pelo autor, 2024.

### 3.7 Coleta de dados

A coleta de dados consistiu em preenchimento de planilha elaborada exclusivamente para esta pesquisa com informações referentes ao grupo que pertencia o dente e sua



identificação numérica. Também foram coletadas a pontuação para cada imagem, tamanho e tipo de fragmento presente, além da mA utilizada, para TCFC (APÊNDICE C).

Para a coleta dos dados das radiografias periapicais digitais também foi utilizada uma planilha separada para identificação dos dentes, tamanho e tipo dos fragmentos (APÊNDICE D). Ademais, nesse caso, foram preenchidas as informações referentes ao aparelho de radiografia e sensor sólido utilizado, de acordo com a avaliação, apenas em vista ortorradial ou com a técnica de Clark.

### 3.7.1 Caracterização da amostra

Os 42 dentes molares foram divididos aleatoriamente em sete grupos, sendo um destes controle, de acordo com adaptação de metodologia proposta por Costa *et al.* (2021): Grupo 1: canais radiculares apenas instrumentados; Grupos 2 e 3: canais radiculares instrumentados e obturados com inserção de fragmentos do instrumento WaveOne Gold, com 3 e 2 mm, respectivamente; Grupos 4 e 5: canais radiculares instrumentados e obturados com inserção de fragmentos do instrumento Reciproc Blue, com 3 e 2 mm, respectivamente; Grupos 6 e 7: canais radiculares instrumentados e obturados com inserção de fragmentos do instrumento ProTaper Next, com 3 e 2 mm, respectivamente. A divisão dos grupos está descrita no quadro 3.

**Quadro 3.** Grupos de estudo, de acordo com a presença de material obturador e/ ou instrumento fraturado.

| Grupo                                      | Instrumentação dos canais | Material obturador | Instrumento fraturado |
|--------------------------------------------|---------------------------|--------------------|-----------------------|
| 1 Grupo Controle (n = 12)                  | X                         |                    |                       |
| 2 (WaveOne Gold + fratura 3 mm);<br>n = 5  | X                         | X                  | X                     |
| 3 (WaveOne Gold + fratura 2 mm);<br>n = 5  | X                         | X                  | X                     |
| 4 (Reciproc Blue + fratura de 3 mm); n = 5 | X                         | X                  | X                     |
| 5 (Reciproc Blue + fratura 2 mm);<br>n = 5 | X                         | X                  | X                     |

|                                            |   |   |   |
|--------------------------------------------|---|---|---|
| 6 (ProTaper Next + fratura 3 mm);<br>n = 5 | X | X | X |
| 7 (ProTaper Next + fratura 2 mm);<br>n = 5 | X | X | X |

**Fonte:** Elaborado pelo autor, 2024.

**3.7.2 Preparo da amostra**

Todos os dentes foram analisados previamente por meio de radiografias periapicais e inspecionados por transluminação, para verificação dos critérios de elegibilidade. Os dentes da amostra foram submetidos à raspagem e alisamento coronorradicular com auxílio de curetas periodontais de Gracey nº 7-8, 9-10, 11-12 e 13-14 (Golgran® Instrumentos Odontológicos, São Caetano do Sul, São Paulo, Brasil). Em seguida, os dentes foram esterilizados em autoclave (M9UltraClave Dabi Atlante, Ribeirão Preto, São Paulo, Brasil), e armazenados em recipientes de plástico (Wellmix® Importação de Utilidades Ltda, Santa Catarina, Brasil). Os recipientes de plástico foram identificados numericamente (FIGURA 2).

**Figura 2.** Recipientes utilizados para armazenamento da amostra.



**Fonte:** Elaborada pelo autor, 2024.

As coroas dos dentes foram seccionadas perpendicularmente ao longo eixo das raízes, na junção amelo-cementária, com ponta diamantada cônica ponta de lápis (FG Invicta® American Burrs, Ribeirão Preto, São Paulo, Brasil) acoplado em peça de mão reta sem irrigação (Gnatus – Produtos Odontológicos, Palhoça, Santa Catarina, Brasil) (FIGURA 3A). Em seguida, o teto da câmara pulpar foi removido com ponta diamantada esférica, e o refinamento

do preparo foi feito com ponta diamantada cônica longa com ponta inativa (FIGURAS 3B e 3C).

**Figura 3.** (A) Finalização do seccionamento da coroa dentária, perpendicularmente ao longo eixo do dente. (B) Refinamento do preparo. (C) Aspecto final do dente preparado para ser instrumentado.



**Fonte:** Elaborada pelo autor, 2024.

#### 3.7.2.1 Preparo dos canais radiculares

Todos os dentes envolvidos na pesquisa tiveram seus canais radiculares instrumentados por um especialista em Endodontia. Para padronização dos preparos, foi utilizado apenas um sistema mecanizado de instrumentação em todos os dentes, sendo utilizado o instrumento endodôntico WaveOne® Gold (Dentsply Sirona Brasil, Catanduva, SP, Brasil), cuja ponta ativa possui 16 mm. Para os canais mesiais padronizou-se a utilização do instrumento PRIMARY (lima 025.07) e para o canal distal utilizou-se o instrumento MEDIUM (lima 035.06). Os instrumentos supracitados foram acoplados no contra-ângulo do motor endodôntico X-Smart Plus Maillefer (Dentsply Sirona Brasil, Catanduva, SP, Brasil) (FIGURA 4).

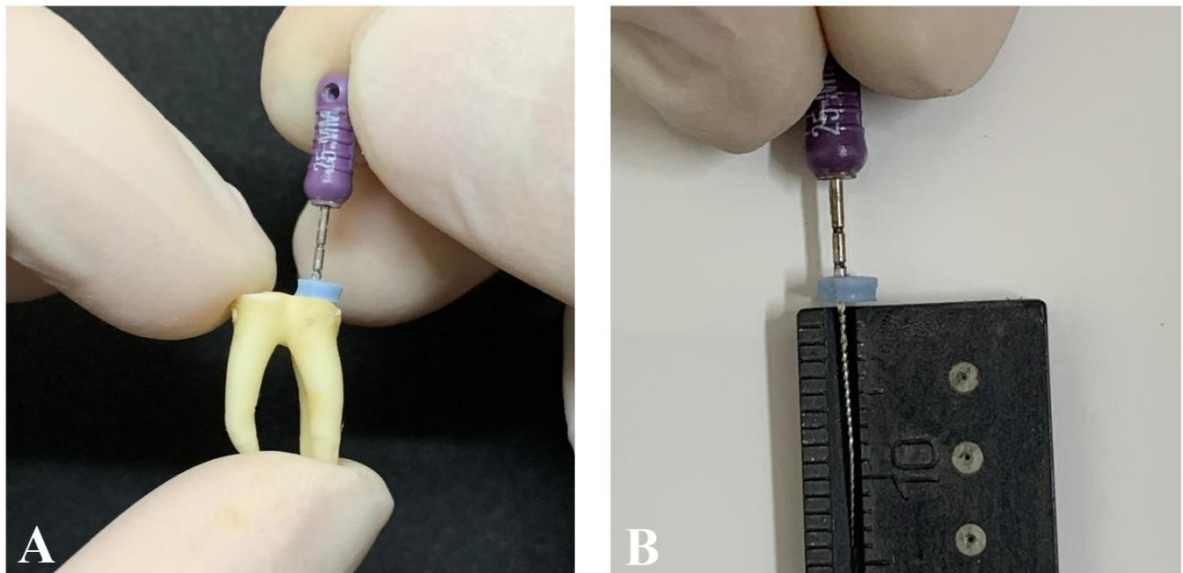
**Figura 4.** Motor endodôntico utilizado para o preparo dos condutos radiculares.



**Fonte:** Google Imagens, 2024.

Seguindo as recomendações do fabricante, foi realizada exploração com lima manual tipo K Especial nº 10 (Dentsply Sirona Brasil, Catanduva, SP, Brasil), e medição dos comprimentos dos canais radiculares (FIGURA 5). Os dentes tiveram seus canais radiculares irrigados com hipoclorito de sódio a 2,5% (Ciclo farma, Serrana, São Paulo, Brasil) com auxílio de uma seringa para irrigação (Ultradent Products Inc., South Jordan, UT, EUA) e agulha Endo-Enze (Ultradent Products Inc., South Jordan, UT, EUA), durante toda a instrumentação mecânica.

**Figura 5.** (A) Exploração e (B) medição do comprimento dos canais radiculares.



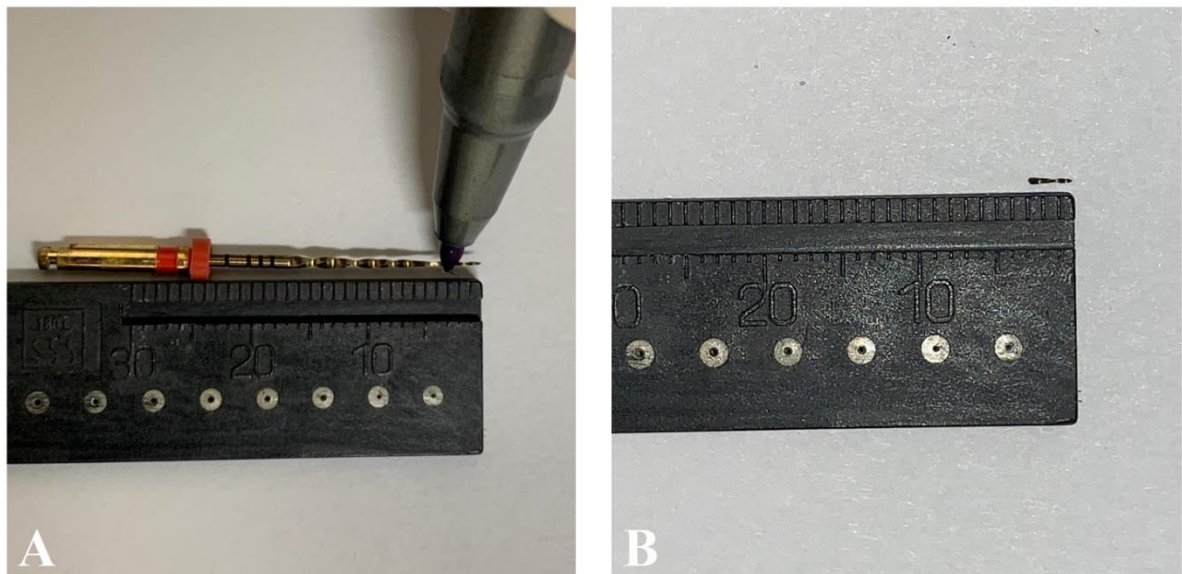
**Fonte:** Elaborada pelo autor, 2024.

Após a instrumentação, os canais radiculares passaram por uma irrigação com 5 ml de ácido etileno diamino tetracético (EDTA) a 17% (Biodinâmica Química e Farmacêutica Ltda, Ibiporã, Paraná, Brasil), por três minutos, sendo agitado com auxílio de uma lima manual especial tipo K Especial nº 8 (Dentsply Sirona Brasil, Catanduva, SP, Brasil), seguida por nova irrigação com 2 ml de NaCl a 2,5 %. Logo após a instrumentação dos canais radiculares, os mesmos foram secos com pontas de papel absorvente esterilizadas Cell Pack do sistema WaveOne Gold Tan Pro G (TANARI Industrial LTDA, Boa Vista, RR, Brasil) (Adaptação de Moreira-Souza *et al.*, 2021).

### 3.7.2.2 Fratura dos instrumentos e obturação dos canais radiculares

Os instrumentos mecanizados WaveOne Gold® PRIMARY (025.07), Reciproc® Blue R25 e ProTaper Next X2 (025.06) foram cortados e inseridos nos canais radiculares mesiovestibulares dos dentes para aquisição das imagens e posterior análise. Os instrumentos foram medidos, a partir da extremidade da ponta ativa, em 2 e 3 mm (de acordo com o grupo de estudo), com régua de alumínio milimetrada endodôntica (Maquira Dental Group, Maringá, PR, Brasil) (FIGURA 6A) e marcados com caneta permanente, para posterior corte com alicate ortodôntico de corte de fio pesado 267 (FAVA, Franco da Rocha, São Paulo, Brasil) (FIGURA 6B), seguindo adaptação da metodologia proposta por Baratto-Filho *et al.* (2020).

**Figura 6.** (A) Delimitação do comprimento do fragmento a ser cortado. (B) Fragmento do instrumento endodôntico após o corte.



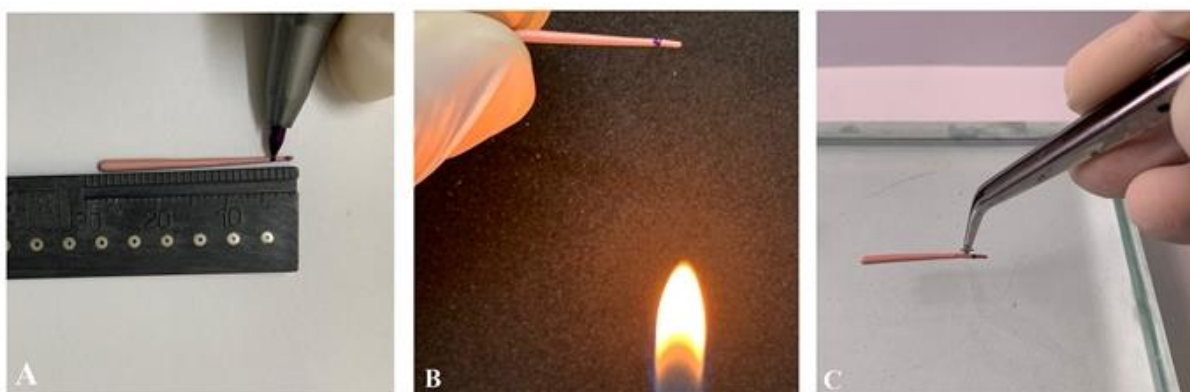
**Fonte:** Elaborada pelo autor, 2024.

Para obturação dos canais radiculares, utilizou-se a técnica do cone único, com os cones de guta-percha *Fine Medium Extra Longo* (FMEL) (Odous de Deus, Belo Horizonte, Brasil). Os cones foram adaptados aos canais radiculares em seus comprimentos de trabalho e compactados verticalmente à frio. O cimento endodôntico utilizado foi o *Sealer Plus* (MK Life – Medical and Dental Products, Porto Alegre, RS, Brasil), com sua manipulação seguindo as recomendações do fabricante. Esse cimento foi pincelado nas paredes dos canais seguido de

inserção do cone de gutapercha para obturação. Por último, a parte do cone de gutapercha em excesso foi cortada horizontalmente, de forma manual, com calcador de Paiva (ICE – Produtos Odontológicos, Jardim Regina, SP, Brasil) aquecido.

Nos canais radiculares que receberam os instrumentos fraturados, os cones de gutapercha foram marcados com caneta permanente, 3 mm aquém do limite apical, para posterior inserção do fragmento (FIGURA 7A). Em seguida, a gutapercha foi aquecida em lamparina à álcool (FIGURA 7B), durante 3 segundos, e com o auxílio de pinça clínica para algodão (Golgran® Instrumentos Odontológicos, São Caetano do Sul, SP, Brasil), o instrumento fraturado foi adaptado e fixado no cone acima da marcação previamente realizada (FIGURA 7C). Os canais radiculares foram obturados com a gutapercha junto com o instrumento fraturado e o cimento endodôntico, garantindo o preenchimento completo do canal radicular.

**Figura 7.** (A) Demarcação da gutapercha 3 mm aquém do limite apical. (B) Aquecimento da gutapercha na lamparina à álcool. (C) Fixação do instrumento fraturado na gutapercha.



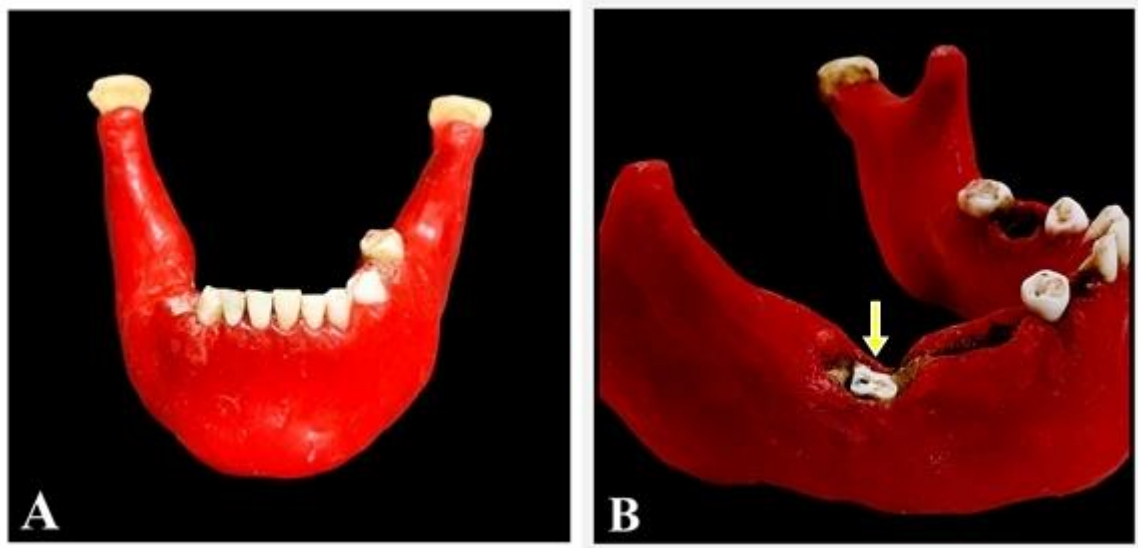
**Fonte:** Elaborada pelo autor, 2024.

### 3.7.3 Preparo da mandíbula

Para simular a interferência dos tecidos moles na formação da imagem, a amostra foi posicionada em uma mandíbula que foi recoberta com uma camada de 5 mm de espessura de cera rosa nº7 (FIGURA 8A). Os dentes foram posicionados nos alvéolos de molares mandibulares envoltos por uma fina camada de cera nº7 (FIGURA 8B). Nas aquisições das imagens tomográficas, a mandíbula foi colocada em uma caixa de isopor retangular contendo água (Pinto *et al.*, 2017).



**Figura 8.** (A) Mandíbula recoberta por cera rosa nº7 utilizada para aquisição das imagens. (B) Dente da amostra posicionado no alvéolo da mandíbula para posterior aquisição de imagens.

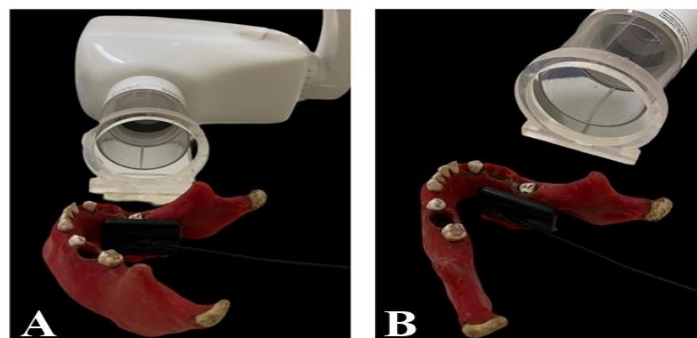


**Fonte:** Elaborada pelo autor, 2024.

### 3.7.4 Aquisição das imagens radiográficas

As imagens radiográficas digitais foram adquiridas em três planos horizontais diferentes: ortorradial, mesiorradial e distorradial. Foi utilizado o aparelho Focus Xray (Kavo dental, Joinville, Brasil), ajustado para 70 kVp, 7 mA e tempo de exposição de 0,06 segundos. Para garantir o plano horizontal, as imagens foram adquiridas utilizando dois dispositivos de acrílico, um para técnica paralela ortorradial e outro para as técnicas mesial e distal (FIGURAS 9A e 9B). Para as aquisições, foi utilizado o sensor sólido RVG 5200 (Carestream Dental, São José dos Campos, SP, Brasil).

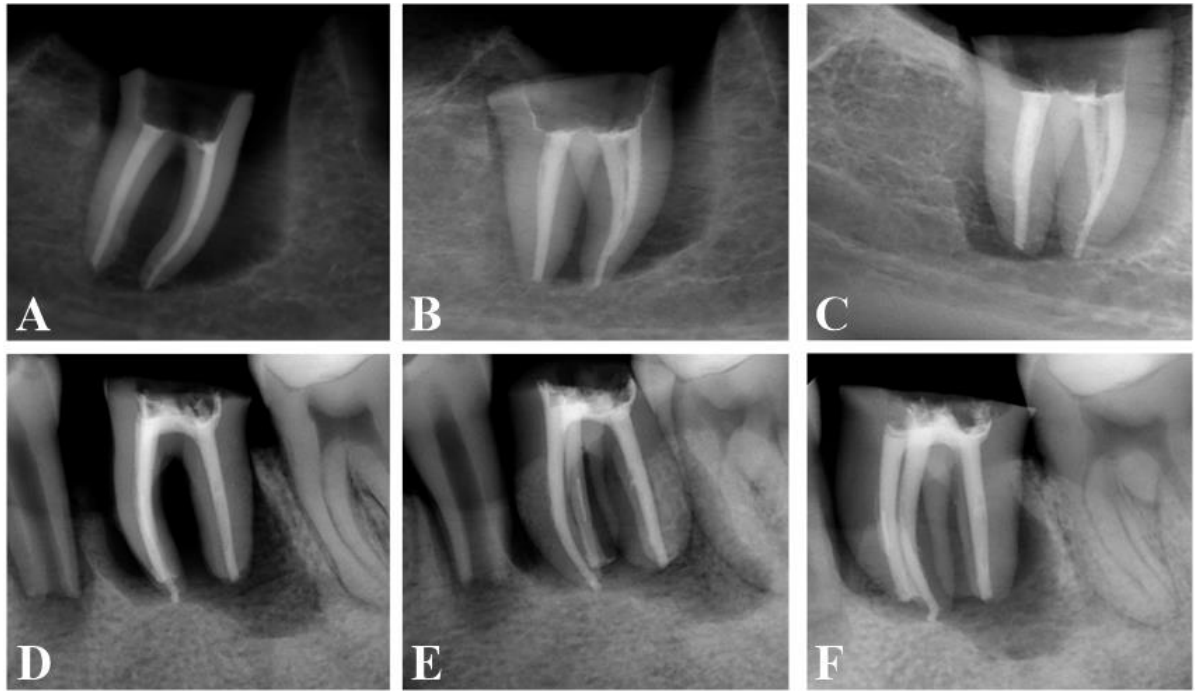
**Figura 9.** Aparelho Focus Xray.



**Fonte:** Elaborada pelo autor, 2024.

As imagens resultantes foram exportadas em formato de arquivo de imagem *Tagged Image File Format* (TIFF), para visualização (FIGURA 10).

**Figura 10.** (A, B, C). Imagens adquiridas de um dente sem a presença de instrumento fraturado. (D, E, F). Imagens adquiridas de um dente com a presença de instrumento fraturado.



**Fonte:** Elaborada pelo autor, 2024.

### 3.7.5 Aquisição das imagens tomográficas

Para aquisição das imagens volumétricas, foi utilizado o aparelho KAVO OP 3D PRO (Kavo Kerr, São Paulo-SP, Brasil), escala de cinza de 16 bit, campo de visão de 5 cm x 5 cm, voltagem do tubo fixa de 90 kV, voxel de 85µm e tempo de exposição de 8.7 s (FIGURA 11). Todas as aquisições foram feitas no modo Endo e cada dente foi submetido a quatro aquisições, alterando a mA em 6,3, 7,1, 8,0 e 9,0.

Ademais, a mandíbula seca com o dente foi colocada dentro de um recipiente contendo água, para aquisição dos volumes.



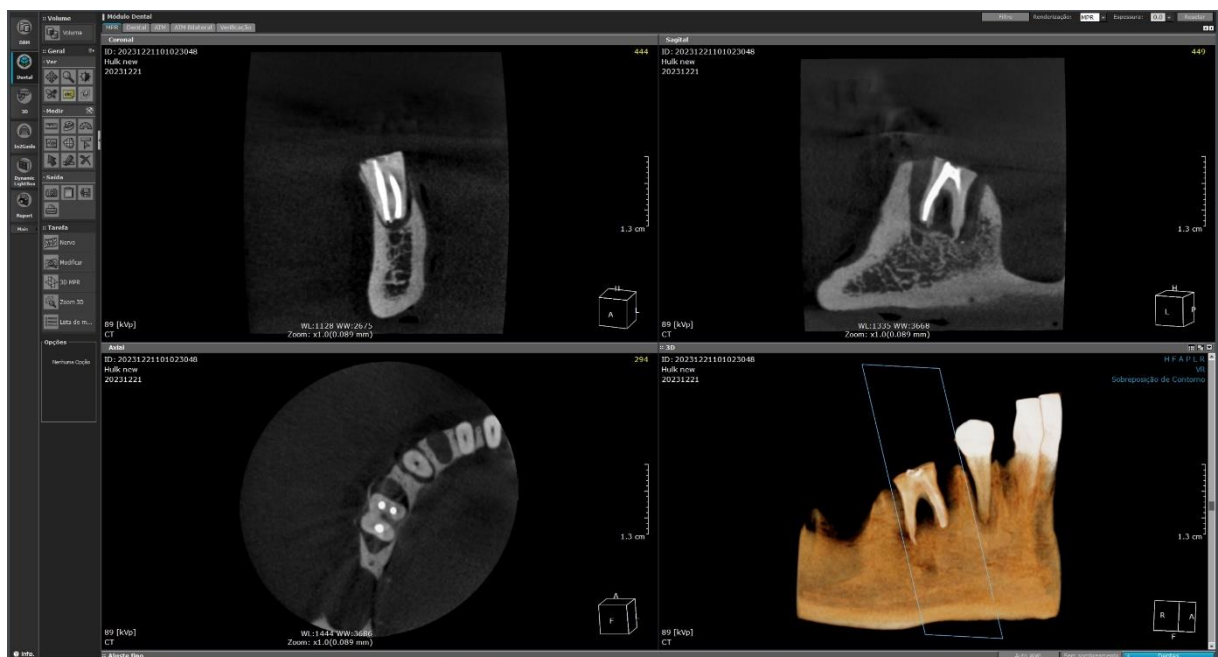
**Figura 11.** Aparelho 3 em 1 KAVO OP 3D PRO utilizado na pesquisa.



**Fonte:** Elaborada pelo autor, 2024.

Após aquisição das imagens (FIGURA 12), todos os volumes foram exportados no formato DICOM (*Digital Imaging and Communications in Medicine*).

**Figura 12.** Interface do programa após realização da TCFC.



**Fonte:** Elaborada pelo autor, 2024.

### 3.7.6 Avaliação das imagens radiográficas e dos volumes gerados

Antes das avaliações das imagens, as mesmas foram randomizadas aleatoriamente, e para cada imagem foi atribuído um código, com auxílio de um gerador de números aleatórios sem repetição (<https://www.invertexto.com/numeros-aleatorios>).

Três especialistas em radiologia oral e maxilofacial avaliaram todas as imagens radiográficas digitais usando o *Microsoft Image Viewer* (Microsoft Corporation, Redmond, EUA), exibido em um monitor colorido de 28 polegadas (Ultra Sharp, Dell Inc., Austin, EUA), colocado em uma sala silenciosa com pouca luz. Todos os observadores estavam cegos para a metodologia do estudo.

As imagens volumétricas foram analisadas também pelos mesmos especialistas. Os examinadores podiam usar ferramentas de *zoom*, brilho e contraste. Além disso, utilizaram o mesmo monitor (Philips D - Clinical, Amsterdã, Países Baixos), de 24 polegadas, 1360x768, para visualização das imagens. O computador utilizado tinha o processador core i7, 32gb de memória RAM e HD SSD de 480gb e placa de vídeo GeForce 8gb 1070.

Para as avaliações das radiografias periapicais digitais e dos volumes, cada examinador avaliou qualitativamente cada canal separadamente quanto à presença/ ausência de um instrumento endodôntico fraturado de acordo com uma escala de classificação de 5 pontos (1, definitivamente ausente; 2, provavelmente ausente; 3, incerteza; 4, provavelmente presente; e 5, definitivamente presente), sem ter conhecimento de quantos dentes tinham instrumentos fraturados (Ramos Brito *et al.*, 2017; Moreira-Souza *et al.*, 2021).

### 3.7.7 Treinamento e calibração

Todos os examinadores passaram por treinamento prévio com apresentação de exemplos aleatórios das imagens radiográficas e dos volumes, além de explanação do que planejava ser identificado nas imagens. Para calcular a concordância inter-observador, foram utilizadas 30% das imagens tomográficas.

## 3.8 Análise estatística

Os dados foram analisados usando o MedCalc (versão 22.0, MedCalc Software Ltd., Ostend, Bélgica). As concordâncias intra e interobservador para as análises dos volumes de

TCFC, nas diferentes correntes do tubo, foram avaliadas usando o índice Kappa, com interpretação baseada na escala de Landis e Koch. As concordâncias interobservadores para as análises das RPD e da TCFC em 6,3 mA foram avaliadas com o coeficiente kappa de Fleiss. As métricas diagnósticas, incluindo a área sob a curva ROC ( $A_z$ ), sensibilidade e especificidade, para detectar instrumentos endodônticos fraturados, foram avaliadas para cada método de avaliação de imagem e de acordo com diferentes fatores do estudo.

Para os resultados da TCFC, a ANOVA *multi-way* com teste *post-hoc* de Tukey foi usada para comparar os resultados com base nos fatores do estudo (nível de corrente do tubo, tamanho do instrumento e sistema de lima endodôntico). Para avaliações radiográficas, a ANOVA *two-way* com testes *post-hoc* de Tukey foi aplicada para comparar os resultados com base no tamanho do instrumento e no sistema de lima endodôntico. Para comparar o desempenho dos dois métodos de imagem, a ANOVA *one-way* com testes *post-hoc* de Tukey foi usada dentro de cada tamanho de instrumento e sistema de lima endodôntico. Se o nível de corrente do tubo não tivesse efeito significativo nos valores de  $A_z$ , o menor nível de mA era selecionado para análise. Um nível de significância de 5% era usado para todas as análises ( $p < 0,05$ ).



## 4 ARTIGOS

### 4.1 Apresentação

O projeto da presente pesquisa ora desenvolvido foi aprovado em qualificação pelo Programa de Pós-Graduação em Odontologia da UEPB. Como resultado da execução deste projeto, dois artigos são apresentados nesta tese com os títulos “*Assessment of separated endodontic instruments on endodontic filled molars using digital periapical radiograph and CBCT: a comparative study*” (Artigo 1); “*CBCT milliamperage settings and their impact on separated instrument detection: An ex vivo study*” (Artigo 2).

Após as devidas considerações da banca avaliadora desta tese, os referidos artigos serão submetidos aos periódicos *Clinical Oral Investigations* (Fator de impacto: 3.1, Qualis Odontologia A1) (Artigo 1) e *Journal of Endodontics* (Fator de impacto: 3.5, Qualis Odontologia A1), cujas normas de submissão de trabalhos encontram-se nos Anexo B e C.

## 4.2 Primeiro artigo a ser submetido

### **Assessment of separated endodontic instruments on endodontic filled molars using digital periapical radiograph and CBCT: a comparative study**

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## Abstract

**Objective.** To compare cone-beam computed tomography (CBCT) and digital periapical radiography (DPR) in the detection of separated endodontic instruments (SI) in fully filled root canals of mandibular molars. **Material and Methods.** Forty-two teeth were filled, and SI (2 and 3 mm) of three types of endodontic instruments (WaveOne® Gold; Reciproc® Blue; Protaper® Next) were inserted into the mesiobuccal canals of 30 of test teeth. CBCT examinations were acquired using KAVO OP 3D PRO device. The Focus Xray device and the RVG 5200 solid sensor was used for DPR images (orthoradial, distal and mesial). All images were evaluated by three experts for the presence or absence of SI on a 5-point scale. Diagnostic metrics, for detecting SI, were evaluated for each imaging assessment method. To compare the performance of imaging methods, a one-way ANOVA with Tukey post-hoc tests was used. The significance level was set at 5% ( $p=0.05$ ). **Results.** Protaper® Next SI CBCT images presented the lowest area under the ROC curve (Az) values (0.58 and 0.56, 2 and 3 mm, respectively) and differed statistically from the other assessed SI images (CBCT and DPR) ( $p<0.05$ ). Overall, DPR presented higher Az, sensitivity and specificity values than CBCT. **Conclusions.** DPR perform better than CBCT images on SI detection in multi-rooted teeth; therefore, should be the imaging modality of choice for the detection of SI. **Clinical Relevance.** When a SI is suspected with or without matching clinical history, it is recommended to use DPR, with variation of the horizontal angle, if necessary.

**Keywords:** Diagnostic imaging. Cone-beam computed tomography. Radiograph, dental, digital. Root canal obturation. Endodontics.



## Introduction

Instrumentation of the root canal system is an important step during endodontic treatment. Failures during endodontic instrumentation such as perforation, occurrence of separated endodontic instrument (SI), ledge, transportation and zipping minimize the efficiency of the therapy [1]. One of the risk factors for SI is the root canal morphology [1]. There are different types of endodontic instruments on the market and all are susceptible to fracture independent of their constitution, if it is stainless steel or nickel-titanium (NiTi) [2,3], and the type of mechanized instrument, rotatory or reciprocating.

The decision for planning the treatment of a SI should be based on an accurate diagnosis, which is ensured primarily by radiographic images. However, radiographic evaluations present several limitations for endodontic treatments [4]. Periapical radiography has certain limitations since it generates a two-dimensional image of a three-dimensional structure [5]. To enable the assessment of the roots of multi-rooted teeth that appear superimposed, in addition to the presence of filling materials due to the two-dimensional nature of the image, radiographic localization techniques such as the Same Lingual Opposite Buccal (SLOB) rule can be used [6].

Cone-beam computed tomography (CBCT) overcomes some limitations of conventional radiography by producing three-dimensional images, allowing comprehensive visualization of the anatomy of structures of interest. Furthermore, slices of volumetric data can be chosen by the clinician and viewed in all orthogonal planes and in non-orthogonal planes [7]. However, CBCT generates artifacts, which is considered the main limitation of the technique [8]. These artifacts are produced when the region of interest contains metallic objects, such as SI, or even root canal filling materials, such as gutta-percha and endodontic sealer [9-12].

There is a scarcity of studies evaluating the accuracy of digital periapical radiography (DPR) and CBCT in detecting SI in root canals. The results of these studies reveal that DPR tends to have better accuracy than CBCT in detecting SI [5,6,8,13-15]. However, little is known about the accuracy of these diagnostic methods, especially in mandibular molar teeth with three fully filled canals, considering the presence of SI, gutta-percha and endodontic sealer. In addition, there are no studies that investigate different types of mechanized instruments in different sizes.

Therefore, the present study aimed to compare CBCT and DPR in the detection of SI in fully filled root canals of first and second mandibular molars.

## Material and Methods

This experimental study was approved by the research ethics committee (no. 6,026,095) and is in compliance with the Helsinki Declaration.

### *Sample preparation*

The study sample was a non-probabilistic convenience sample, consisting of 42 mandibular molar teeth. First and second mandibular molars with fully formed roots, without fused or supernumerary roots, without excessive apical curvature, without root caries and with three root canals were included. Teeth with previous endodontic treatment, presence of pulp nodules, perforation or visible signs of root fracture were excluded from the sample.

All teeth were previously analyzed using periapical radiographs and inspected by translumination to verify the eligibility criteria. The sample teeth were subjected to scaling and crown-root smoothing with the aid of Gracey periodontal curettes no. 7-8, 9-10, 11-12 and 13-14 (Golgran<sup>®</sup> Instrumentos Odontológicos, São Caetano do Sul, São Paulo, Brazil). All teeth were then sterilized in an autoclave (M9UltraClave Dabi Atlante, Ribeirão Preto, São Paulo, Brazil) and stored in numerically identified plastic containers (Wellmix<sup>®</sup> Importação de Utilidades Ltda, Santa Catarina, Brazil).

The crowns of the teeth were sectioned perpendicularly to the long axis of the roots, at the cemento-enamel junction, with a conical pencil-point diamond bur (FG Invicta<sup>®</sup> American Burrs, Ribeirão Preto, São Paulo, Brazil) attached to a straight handpiece without irrigation (Gnatus – Produtos Odontológicos, Palhoça, Santa Catarina, Brazil). Then, the roof of the pulp chamber was removed with a spherical diamond bur, and the preparation was refined with a long conical diamond bur with an inactive tip.

All teeth involved in the research had their root canals instrumented by an Endodontics specialist. To standardize the preparations, only one mechanized instrumentation system the WaveOne<sup>®</sup> Gold endodontic instrument with active tip of 16 mm was used on all teeth. For the mesial canals, the use of a PRIMARY instrument (file 025.07) was standardized, and for the distal canal, a MEDIUM instrument (file 035.06) was used. The instruments were coupled to the contra-angle of the X-Smart Plus Maillefer endodontic motor (Dentsply Sirona, Catanduva, SP, Brazil).

Following the manufacturer's recommendations, exploration was performed with a manual file type K Special No. 10 (Dentsply Sirona Brazil, Catanduva, SP, Brazil), and the lengths of the root canals were measured. The teeth had their root canals irrigated with 2.5% sodium hypochlorite (Ciclo farma, Serrana, São Paulo, Brazil) with the aid of an irrigation syringe (Ultradent Products Inc., South Jordan, UT, USA) and Endo-Enze needle (Ultradent Products Inc., South Jordan, UT, USA), throughout the mechanical instrumentation.

After instrumentation, the root canals were irrigated with 5 ml of 17% ethylene diamine tetracetic acid (EDTA) (Biodinâmica Química e Farmacêutica Ltda, Ibiaporã, Paraná, Brazil) for three minutes, agitated with the aid of a special manual endodontic instrument type K Especial nº 8 (Dentsply Sirona Brasil, Catanduva, SP, Brazil), followed by new irrigation with 2 ml of 2.5% NaCl. Immediately after instrumentation of the root canals, the canals were dried with sterilized Cell Pack absorbent paper points from the WaveOne® Gold Tan Pro G system (TANARI Industrial LTDA, Boa Vista, RR, Brazil), based on an adapted version of Moreira-Souza et al. [16] methodology.

Canal obturation was done using single cone technique, with Fine Medium Extra Long (FMEL) gutta-percha cones (Odous de Deus, Belo Horizonte, Brazil). The cones were adapted to the root canals at their working lengths and compacted by vertical cold compaction technique. The cones were cemented using Sealer Plus (MK Life – Medical and Dental Products, Porto Alegre, RS, Brazil), following the manufacturer's recommendations. This cement was brushed onto the canal walls followed by insertion of the gutta-percha cone for obturation. Finally, the excess of the gutta-percha cones was cut horizontally, manually, with a heated Paiva presser (ICE – Produtos Odontológicos, Jardim Regina, SP, Brazil).

The sample was randomly divided into seven groups, including a control group (n=12), according to Table 1. The mechanized instruments WaveOne® Gold PRIMARY (025.07), Reciproc® Blue R25 and ProTaper® Next X2 (025.06) were cut and inserted into the mesiobuccal root canals of the test teeth for image acquisition and subsequent analysis. The instruments were measured, from the end of the active tip, at 2 and 3 mm (according to the study group) (Baratto-Filho et al., 2020). With an endodontic millimeter aluminum ruler (Maquira Dental Group, Maringá, PR, Brazil) and marked with a permanent pen, for subsequent cutting with heavy wire cutting orthodontic pliers 267 (FAVA, Franco da Rocha, São Paulo, Brazil).

In the root canals that received the SI, the gutta-percha cones were marked with a permanent pen, 3 mm below the apical limit, for subsequent insertion of the SI. Then, the gutta-percha was heated using an alcohol lamp for 3 seconds, and with the aid of clinical cotton

tweezers (Golgran<sup>®</sup> Instrumentos Odontológicos, São Caetano do Sul, SP, Brazil), the SI was adapted and fixed in the cone above the previously made mark (Figure 1). The root canals were filled with gutta-percha together with the SI and endodontic cement, ensuring complete filling of the root canal.

### *Imaging procedure*

To simulate soft tissue coverage, all teeth were positioned in the #36 and #46 sockets, according to the side of the tooth, of a mandible that was also covered with a 5 mm thick layer of wax No. 7. During CBCT scan acquisition, the mandible was placed in a rectangular Styrofoam box containing water [9,17].

DPR were acquired in three different horizontal planes: orthoradial, mesioradial and distoradial, both with 30° angle. To ensure the horizontal plane, the images were acquired using an acrylic device that allowed acquisition with variation of horizontal angle. The Focus Xray device (Kavo dental, Joinville, Brazil) was used, adjusted to 70 kVp, 7 mA and exposure time of 0.06 seconds. RVG 5200 sensor (Carestream Dental, São José dos Campos, SP, Brazil) was used for DPR acquisition. The resulting images were exported in Tagged Image File Format (TIFF) (Figure 2).

For CBCT scans acquisition, KAVO OP 3D PRO (Kavo Dental, Biberach an der Riß, Germany) scanner was used. The acquisition parameters were set at 5 cm × 5 cm Field of View (FOV), 90 kVp, 6.3 mA, 85 µm voxel and exposure time of 8.7 s. After image acquisition (Figure 3), all volumes were exported in DICOM (Digital Imaging and Communications in Medicine) format.

### *Image evaluation*

The images were randomized, and each image was assigned a code, using a random number generator without repetition (<https://www.invertexto.com/numeros-aleatorios>). Three experts in oral and maxillofacial radiology, with six years of experience, evaluated all DPR using Microsoft Image Viewer (Microsoft Corporation, Redmond, USA). The experts examined the radiographic images in two moments, in the first moment they only evaluated the images in the orthoradial plane, and in the second moment they evaluated the groups of images in the ortho, mesioradial and distoradial planes.

The CBCT examinations were also analyzed by the same experts using OnDemand 3D™ software (CyberMed Corporation, East Brunswick, United States). The examiners were allowed to use the software's zoom, brightness and contrast tools. In addition, they used the same monitor (Philips D - Clinical, Amsterdam, Netherlands), 24 inches, 1360x768, to view the DPR and CBCT examinations. The computer used had a Core i7 processor, 32GB of RAM, a 480GB SSD HD, and an 8GB GeForce 1070 video card. The monitor and computer were placed in a quiet room with dimmed light. All observers were blinded to the study methodology.

For the evaluations of DPR and CBCT examinations, each examiner qualitatively assessed the mesiobuccal canals for the presence/absence of a SI according to a 5-point grading scale (1, definitely absent; 2, probably absent; 3, uncertainty; 4, probably present; and 5, definitely present), without having knowledge of how many teeth had SI [5,16].

All examiners underwent prior training with presentation of random examples of radiographic images and volumes, in addition to an explanation of what was planned to be identified in the images. To calculate intra- and inter-observer agreement, 30% of the images for each image modality separately were used.

### *Statistical analysis*

Data were analyzed using MedCalc (version 22.0, MedCalc Software Ltd., Ostend, Belgium). Diagnostic metrics, including sensitivity, specificity, and the area under the ROC curve (Az) for detecting SI, were evaluated for each imaging assessment method and according to different study factors. Fleiss's kappa coefficient was used to assess agreement between the three evaluators [18].

For radiographic assessments, two-way ANOVA with Tukey post-hoc tests were applied to compare results based on instrument size and endodontic file system. To compare the performance of different imaging assessment approaches, one-way ANOVA with Tukey post-hoc tests were used within each instrument size and endodontic file system. A significance level of 5% was used for all analyses.

## **Results**

In the orthoradial incidence, the overall result found was 0.324 ( $p < 0.0001$ ), indicating weak agreement. In the ortho-mesio-distorradiol incidences, the overall result found was 0.575 ( $p < 0.0001$ ), indicating moderate agreement. Regarding the analysis of CBCT

examination, the kappa value result was -0.058 ( $p > 0.05$ ), indicating an agreement lower than expected by chance (disagreement).

Comparing DPR images at orthoradial with three incidences (orthoradial, mesioradial and distoradial), no statistically significant differences ( $p > 0.05$ ) were found. Reciproc® Blue instrument (size 3 mm) showed excellent Az, sensitivity and specificity values for SI detection, both in the orthoradial incidence (0.97, 1.00, 0.95, respectively) and in the three assessed incidences (0.93, 1.00, 0.86, respectively). In general, when SI detection was based on the three incidences, better values of Az, sensitivity and specificity were obtained (Table 2).

Regarding the comparison of the diagnostic performance for DPR and CBCT in the identification of SI, a statistically significant difference was observed for the Protaper® Next instrument ( $p < 0.05$ ), with a worse Az value for CBCT (0.58 for 2 mm; 0.56 for 3 mm) compared to DPR in one (0.77 for both SI sizes) and in three incidences (0.92 for 2 mm and 0.85 for 3 mm) (Table 3). Overall, there was a better performance in identifying SI using DPR. There was only a good Az (0.81) and excellent sensitivity (0.93) in identifying the WaveOne® Gold instrument in CBCT of size 3 mm.

## Discussion

The present study aimed to compare SI detection using DPR and CBCT images and a statistically significant difference was observed only for Protaper® Next instrument, presenting better results using DPR. There was a better performance of DPR compared to CBCT, in all cases, especially for the three incidences group. In CBCT, only the WaveOne® Gold instrument presented better Az and sensitivity results.

Several imaging modalities can be used to evaluate the outcome of root canal treatments [13]. In this study, DPR and CBCT were evaluated. In the DPR analysis, the Az, sensitivity and specificity values improved when analyzed in the three incidences. Ramos Brito et al. [5] also compared DPR acquired in different incidences using two brands of photostimulable phosphor plates (PSPs) obtaining average diagnostic values were observed in the orthoradial incidence (Az, 0.817, sensitivity, 0.658, specificity, 0.950). and in three incidences (Az, 0.784, sensitivity, 0.542, specificity, 0.975). However, in the mentioned study, the root canals were not completely filled with gutta-percha, what differs from a clinical assessment of an endodontic filled tooth.

In this study, all root canals were filled with gutta-percha, and the SI were inserted together with the heated gutta-percha and endodontic sealer. Gutta-percha, SI and endodontic sealers are radiopaque materials with the aim of enabling the clinician to distinguish them from dental tissues. When all roots are endodontic filled, the overlapping of the roots on the orthoradial incidence has an increased radiodensity compared to non-filled roots. Therefore, in clinical conditions, root overlapping of endodontically treated teeth would decrease orthoradial incidence SI diagnostic and the different incidences would decrease root overlapping and allow better visualization of SI, as observed in this study.

The endodontic sealer used in this study was Sealer Plus, which according to the manufacturer Sealer Plus has a composition similar to AH Plus, an endodontic sealer already well established in the market, containing calcium tungstate and zirconium oxide [19]. Calcium tungstate and zirconium oxide are composed of high atomic number elements which gives the sealer its radiopacity in radiographic images. Although Sealer Plus has lower radiopacity than other endodontic sealers, it has more than the minimum required values recommended by the ISO 6876/2012 specifications [19-21].

Although there were no statistically significant differences between the SI assessed in this study, there were excellent accuracy, sensitivity and specificity values in the identification of the Reciproc<sup>®</sup> Blue size 3 mm SI, in one and three incidences ( $p > 0.05$ ). A rotary instrument, the Protaper<sup>®</sup> Next, and two reciprocating instruments, WaveOne<sup>®</sup> Gold and Reciproc<sup>®</sup> Blue, were assessed and the difference between the two reciprocating instruments is due to their different treatment processes. The thickness of Reciproc<sup>®</sup> Blue instrument is between 60 and 80 nm and the thickness of WaveOne<sup>®</sup> Gold between 100 and 140 nm [22]. Based on our findings, these are probably not determining factors for their radiographic differentiation, as there was no significant statistical differences between them.

While WaveOne<sup>®</sup> Gold's cutting cross section is parallelogram-shaped with two equal sides, providing one or two cutting edges [23], Reciproc<sup>®</sup> Blue has an inverted "S" cutting cross section, providing two cutting edges that can be active simultaneously. The Protaper<sup>®</sup> Next has a rectangular cutting cross section, different from the other assessed instruments. Therefore, the cross-section shape of the endodontic instrument may influence its radiographic visualization independently of the SI size.

When comparing the performances between DPR and CBCT, a statistically significant difference was observed for Protaper<sup>®</sup> Next 3 mm SI on CBCT scans ( $p < 0.05$ ). Other similar studies also observed better performance when identifying SI in DPR [5,6,8,13-15]. Rosen et al. [6] evaluated the presence of SI in fully filled single-rooted teeth with stainless

steel SI finding DPR mean sensitivity and specificity of 71.25%, and 93.75%, respectively and CBCT sensitivity and specificity of 41.25% and 71.25%, respectively. Baratto-Filho et al. [15] assessed SI in fully filled mandibular molars and compared three CBCT scanners with DPR and only nine SI were identified in DPR (37.5%) and none in the CBCT protocols ( $p > 0.05$ ). Although CBCT performance was inferior when compared to DPR in our study, CBCT had a relatively good performance when compared to previous studies.

When assessing SI in the absence of filling material, previous studies obtained excellent accuracy for CBCT [5,15]. In the study by Aleman et al. [15], non-filled groups showed no significant difference between all tested imaging modalities, with CBCT presenting accuracy, sensitivity and specificity of 0.889, 0.900 and 0.889, respectively. In agreement with Ramos-Brito et al. [5], Az, sensitivity and specificity values (0.904, 0.850, and 0.925, respectively). As seen in the mentioned studies, the performance of CBCT depends on the absence of endodontic filling. When the region of interest contains metallic objects (restorations, implants, endodontic instruments) or root canal fillings, the high atomic number and density of these materials lead to the generation of artifacts [10,24]. High-density and high atomic number filling materials produce artifacts in CBCT scans; thus, compromising the detection of SI [13].

Interobserver agreement was considerably weak to moderate for DPR and for CBCT an agreement lower than expected by chance. Despite training and calibration of the evaluators, detection SI is hard in completely filled roots and the prevalence of SI is relatively small (approximately 3.4%) [1]. This low prevalence can influence assessments, based on the personal experience of each specialist. However, this type of study becomes relevant to determine the best method for identifying SI, in the presence or absence of clinical history.

This study was the first to compare DPR and CBCT in detecting different types of mechanized instruments in different sizes, in fully filled mandibular molar teeth. Despite this, the sample is considered small and different CBCT scanners and DPR devices were not used. In addition, because this is an ex vivo study, it is difficult to accurately reproduce the conditions of the living organism, which may affect the results in some way. Therefore, further studies are needed with larger samples, with other types of endodontic instruments, and other types of devices with different exposure protocols.



## Conclusion

Within the limitations of this study, it is concluded that, regarding DPR, performing three incidences was better than one, however, if the diagnosis is possible with a smaller number of radiographs, there is no need for more, aiming to reduce the dose to the patient. DPR performed better than CBCT. Furthermore, the type of file may influence its detection, depending on the diagnostic method.

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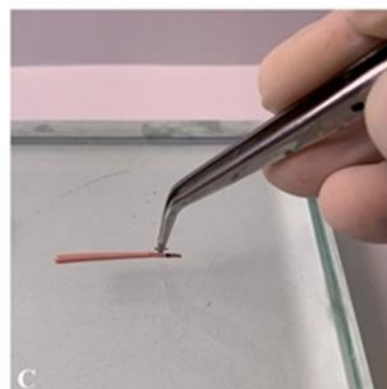
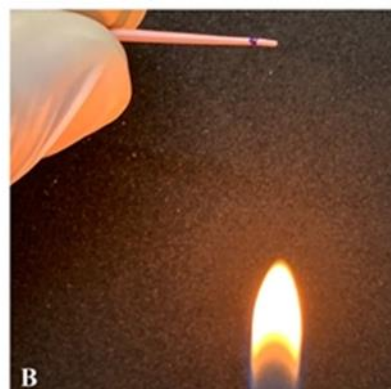
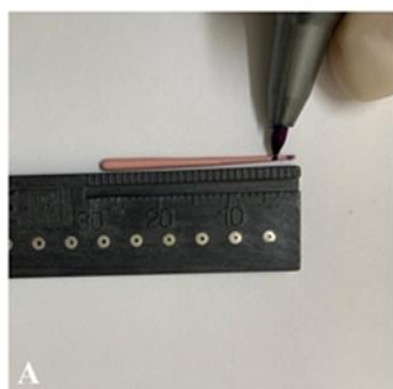
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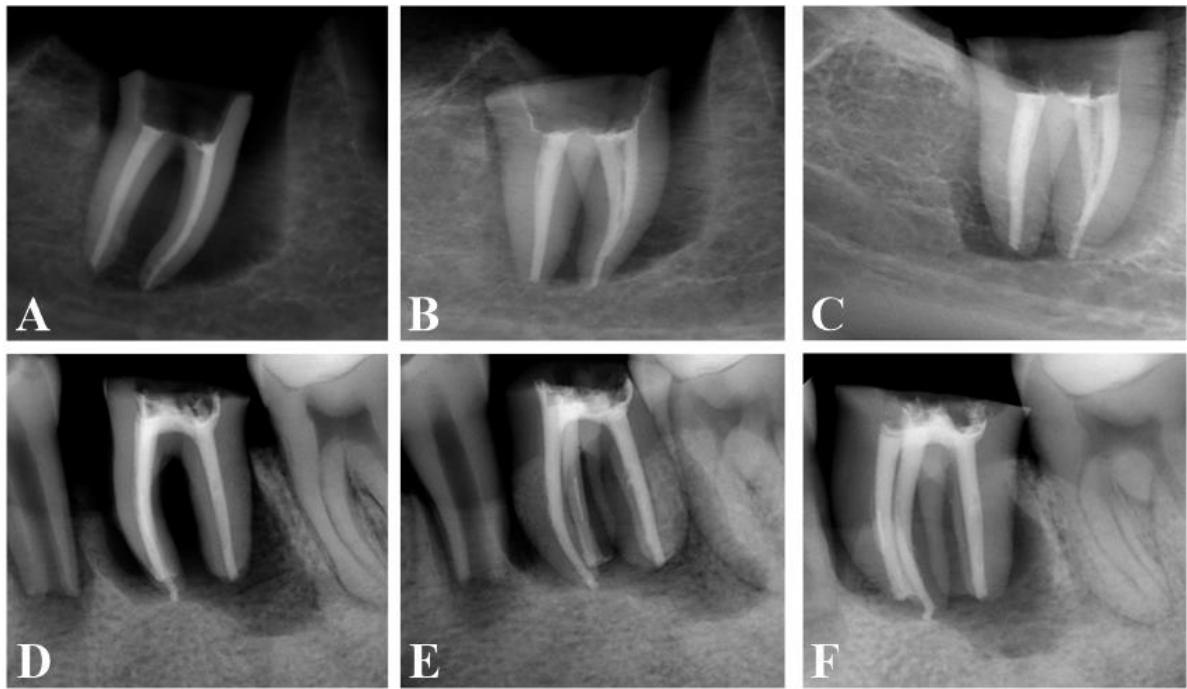
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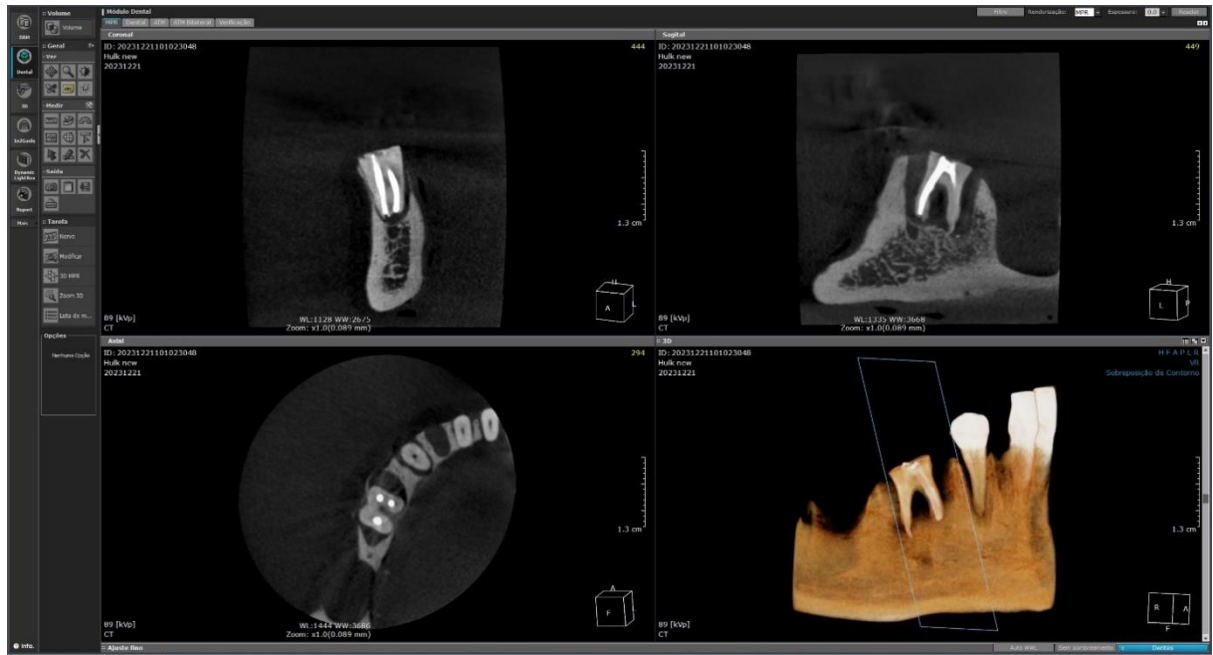
**Figure 1.** (A) Demarcation of the gutta-percha 3 mm below the apical limit. (B) Heating of the gutta-percha in an alcohol lamp. (C) Fixation of the SI in the gutta-percha.

**Figure 2.** (A, B, C). Images acquired from a tooth without the presence of a SI. (D, E, F). Images acquired from a tooth with the presence of a SI.

**Figure 3.** Program interface after performing the CBCT.







**Table 1.** Study groups, according to the presence of filling material and/or SI.

| Group (n)        | n  | Size of SI (mm) |
|------------------|----|-----------------|
| 1 Control Group  | 12 | NA              |
| 2 WaveOne® Gold  | 5  | 3               |
| 3 WaveOne® Gold  | 5  | 2               |
| 4 Reciproc® Blue | 5  | 3               |
| 5 Reciproc® Blue | 5  | 2               |
| 6 ProTaper® Next | 5  | 3               |
| 7 ProTaper® Next | 5  | 2               |

NA, not applicable; SI, separated endodontic instrument.



**Table 2.** Mean (standard deviation) values for the diagnostic metrics related to the detection of SI in radiographic assessments, based on one and three radiographic incidences.

| Size | System        | 1 Image / Incidence |             |             | 3 Images / Incidences |             |             |
|------|---------------|---------------------|-------------|-------------|-----------------------|-------------|-------------|
|      |               | Az                  | Sensitivity | Specificity | Az                    | Sensitivity | Specificity |
| 2 mm | WaveOne Gold  | 0.73 (0.21)         | 0.60 (0.35) | 0.92 (0)    | 0.86 (0.06)           | 0.87 (0.12) | 0.83 (0)    |
|      | Reciproc Blue | 0.77 (0.21)         | 0.67 (0.31) | 0.86 (0.10) | 0.81 (0.11)           | 0.80 (0.20) | 0.86 (0.05) |
|      | Protaper Next | 0.87 (0.10)         | 0.87 (0.11) | 0.86 (0.10) | 0.92 (0.006)          | 0.93 (0.11) | 0.86 (0.05) |
| 3 mm | WaveOne Gold  | 0.78 (0.04)         | 0.80 (0.20) | 0.75 (0.29) | 0.82 (0.17)           | 0.80 (0.35) | 0.83 (0)    |
|      | Reciproc Blue | 0.97 (0.02)         | 1.00 (0)    | 0.95 (0.05) | 0.93 (0.02)           | 1.00 (0)    | 0.86 (0.05) |
|      | Protaper Next | 0.84 (0.04)         | 0.80 (0)    | 0.95 (0.05) | 0.85 (0.06)           | 0.87(0.11)  | 0.86 (0.05) |

Az, Area under the ROC curve

None of the factors had a significant effect on any of the diagnostic metrics ( $p > 0.05$ )

**Table 3.** Comparison of diagnostic performance for detecting SI using one radiographic incidence, three radiographic incidences, and cone-beam computed tomography.

| Diagnostic Metric | Size | System        | 1 Image/Incidence | 3 Images/Incidences | CBCT          |
|-------------------|------|---------------|-------------------|---------------------|---------------|
|                   |      |               | Mean (SD)         |                     |               |
| Az                | 2 mm | WaveOne Gold  | 0.73 (0.21) A     | 0.86 (0.06) A       | 0.68 (0.06) A |
|                   |      | Reciproc Blue | 0.77 (0.21) A     | 0.81 (0.11) A       | 0.65 (0.06) A |
|                   |      | Protaper Next | 0.77 (0.21) A     | 0.92 (0.006) A      | 0.58 (0.07) B |
|                   | 3 mm | WaveOne Gold  | 0.77 (0.21) A     | 0.82 (0.17) A       | 0.81 (0.11) A |
|                   |      | Reciproc Blue | 0.77 (0.21) A     | 0.93 (0.02) A       | 0.67 (0.15) A |
|                   |      | Protaper Next | 0.77 (0.21) A     | 0.85 (0.06) A       | 0.56 (0.06) B |
| Sensitivity       | 2 mm | WaveOne Gold  | 0.60 (0.23) A     | 0.87 (0.07) A       | 0.67 (0.23) A |
|                   |      | Reciproc Blue | 0.67 (0.31) A     | 0.80 (0.20) A       | 0.67 (0.42) A |
|                   |      | Protaper Next | 0.87 (0.12) A     | 0.93 (0.11) A       | 0.53 (0.50) A |
|                   | 3 mm | WaveOne Gold  | 0.80 (0.20) A     | 0.80 (0.35) A       | 0.93 (0.11) A |
|                   |      | Reciproc Blue | 1.00 (0) A        | 1.00 (0) A          | 0.60 (0.53) A |
|                   |      | Protaper Next | 0.80 (0) A        | 0.87 (0.11) A       | 0.53 (0.50) A |
| Specificity       | 2 mm | WaveOne Gold  | 0.92 (0) A        | 0.83 (0) A          | 0.72 (0.25) A |
|                   |      | Reciproc Blue | 0.86 (0.10) A     | 0.86 (0.05) A       | 0.67 (0.33) A |
|                   |      | Protaper Next | 0.86 (0.10) A     | 0.86 (0.05) A       | 0.67 (0.33) A |
|                   | 3 mm | WaveOne Gold  | 0.75 (0.29) A     | 0.83 (0) A          | 0.67 (0.33) A |
|                   |      | Reciproc Blue | 0.95 (0.05) A     | 0.86 (0.05) A       | 0.75 (0.22) A |
|                   |      | Protaper Next | 0.95 (0.05) A     | 0.86 (0.05) A       | 0.67 (0.33) A |

Az, Area under the ROC curve; CBCT, Cone-beam computed tomography.

Different uppercase letters indicate statistically significant differences among the assessment approaches within each endodontic instrument size and endodontic file system ( $p < 0.05$ ).

### 4.3 Segundo Artigo a Ser Submetido

#### **CBCT milliamperage settings and their impact on separated instrument detection: An *ex vivo* study**

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## Abstract

**Introduction:** Depending on the type of the separated endodontic instrument (SI), as well as the materials used to filling the root canals, changes in the exposure parameters may interfere with its detection. Thus, the aim of this study was to evaluate the impact of different tube currents on the detection of SI in cone-beam computed tomography (CBCT). **Methods:** Forty-two teeth were endodontically filled, and three types of endodontic instruments (WaveOne® Gold, Reciproc® Blue, and Protaper® Next) measuring 2 and 3 mm in size were inserted into the mesiobuccal canals of 30 test teeth. CBCT examinations were acquired using the KAVO OP 3D PRO device, with a 5 cm × 5 cm Field of View, 90 kVp, and mA settings varying from 6.3, 7.0, 8.0, to 9.0. All images were evaluated by three oral and maxillofacial radiologists for the presence or absence of SI on a 5-point scale. Multi-way ANOVA and Tukey post-hoc tests were used. **Results:** The identification of the WaveOne® Gold SI at 3 mm size was significantly higher than the others SI evaluated in Az, at all tube currents evaluated ( $p < 0.05$ ). In contrast, the Protaper® Next 3 mm SI had the worst sensitivity values, in all tube currents evaluated ( $p < 0.05$ ). **Conclusion:** WaveOne® Gold SI are better identified in CBCT images than other similar SI available in the market, regardless of the chosen tube current setting. Therefore, when a suspects of the presence of SI, lower tube current settings are recommended.

**Keywords:** Diagnostic imaging. Cone-beam computed tomography. Endodontics.

## Introduction

The success of root canal therapy depends on accurate diagnosis, proper access cavity preparation, and effective cleaning, desinfection, shaping, and root filling techniques<sup>1</sup>. During root canal treatment, proper instrumentation of the canal system is essential. Errors such as perforation, ledge creation, canal transportation, zipping, and instrument separation can undermine the efficacy of the procedure<sup>2</sup>. In particular, the separated endodontic instrument (SI) can impair cleaning, shaping, and root filling of the canal system. As SI negatively impacts treatment success, managing it presents a challenge for clinicians<sup>1</sup>.

Complex endodontic cases, such as SI in root canals, may necessitate the use of cone-beam computed tomography (CBCT) for accurate diagnosis<sup>3</sup>. Small field of view (FOV) CBCT scans with high spatial resolution are preferred for the diagnosis and management of endodontic problems. These scans reduce the volume of tissue exposed and the effective radiation dose, and they also decrease scatter, which improves image quality<sup>4</sup>. The radiation dose produced by a CBCT system depends on multiple factors, such as the rotation extent of the X-ray source and detector, and the FOV size. Other influencing factors include the amount and type of beam filtration, and the tube voltage (kVp), voxel size, and tube current (mA) settings<sup>5-7</sup>.

Contrast resolution and contrast-to-noise ratio are also crucial factors in image quality. Contrast resolution refers to an imaging modality's ability to display small differences in gray levels within the image signal. Noise, which represents the variability in voxel values unrelated to the signal, can impact both spatial and contrast resolution<sup>8</sup>. An increase in kV and mA leads to greater radiation exposure and a reduction in image noise<sup>9</sup>. However, the presence of metallic objects such as restorations, implants, endodontic instruments, or root canal fillings in the area of interest can create artifacts due to their high atomic number and density<sup>10</sup>. These high-density materials interfere with CBCT scans, making it difficult to accurately detect materials such as SI<sup>11</sup>.

Image optimization strategies are tailored to the specific diagnostic needs. Additionally, subjective enhancements in image quality do not always translate into better diagnostic accuracy and might result in increased radiation exposure for the patient. Furthermore, it is the responsibility of the operator or radiologist to choose the settings, which will directly impact the image quality<sup>8</sup>. To date, there are no studies that evaluate several tube currents from the same device for the identification of different types of endodontic instruments. Thus, the objective of the present study was to evaluate the impact of different mA values on the identification of SI in CBCT.

## Material and Methods

This experimental study received approval from the research ethics committee (approval number 6,026,095). Furthermore, this study is in accordance with the Declaration of Helsinki.

### *Eligibility criteria*

A non-probabilistic convenience sampling method was employed for this study, which included 42 mandibular molar teeth. Criteria for inclusion were first and second mandibular molars with fully developed roots, no fused or supernumerary roots, no significant apical curvature, no root caries, and with two roots and three root canals. Teeth with a history of endodontic treatment, pulp nodules, perforations, or visible root fractures were excluded. All teeth were evaluated using periapical radiographs and inspected through translumination to confirm they met the eligibility criteria. All teeth were treated and had their crowns cut, according to the methodology proposed by Baratto-Filho et al.<sup>12</sup>. And the teeth had their root canals instrumented by an endodontic specialist.

For root canal obturation, single cone technique was employed using Fine Medium Extra Long (FMEL) gutta-percha cones (Odous de Deus, Belo Horizonte, Brazil). The cones were fitted to the working lengths of the root canals and vertically compacted with cold techniques. Sealer Plus (MK Life – Medical and Dental Products, Porto Alegre, RS, Brazil) was used as the endodontic cement, applied according to the manufacturer's instructions. This cement was brushed onto the canal walls before the gutta-percha cone was inserted for obturation. Excess gutta-percha was then trimmed horizontally using a heated Paiva presser (ICE – Produtos Odontológicos, Jardim Regina, SP, Brazil).

For image acquisition and subsequent analysis, the mechanized instruments WaveOne Gold® PRIMARY (025.07), Reciproc® Blue R25, and ProTaper® Next X2 (025.06) were sectioned and inserted into the mesiobuccal root canals of the teeth. The instruments were measured from the end of the active tip at 2 and 3 mm, as per the study group<sup>12</sup>. Measurements were made using an endodontic millimeter aluminum ruler (Maquira Dental Group, Maringá, PR, Brazil) and marked with a permanent pen before being cut with heavy wire cutting orthodontic pliers 267 (FAVA, Franco da Rocha, São Paulo, Brazil).

### *Insertion of separated endodontic instrument*

In the root canals containing SI, the gutta-percha cones were marked 3 mm below the apical limit with a permanent pen to guide the placement of the SI. The gutta-percha was then heated over an alcohol lamp for 3 seconds. Using clinical cotton tweezers (Golgran® Instrumentos

Odontológicos, São Caetano do Sul, SP, Brazil), the SI was positioned and secured above the marking on the gutta-percha cone. The root canals were then filled with gutta-percha, incorporating the SI and endodontic cement to ensure thorough root canal obturation.

#### *Sample categorization*

The teeth were randomly assigned to seven groups, including a control group. Three types of mechanized endodontic instruments were utilized: WaveOne® Gold (Dentsply Sirona, North Carolina, USA), ProTaper® Next (Dentsply Maillefer, Ballaigues, Switzerland), and Reciproc® Blue (VDW GmbH, München, Germany), each available in two sizes (2 mm and 3 mm). The groups were divided as follows: Group 1 (control): teeth instrumented and filled without the presence of the SI (n = 12); Group 2 (WaveOneGold): instrumented and filled teeth with the presence of SI size 3 mm (n = 5); Group 3 (WaveOne Gold): instrumented and filled teeth with the presence of SI size 2 mm (n = 5); Group 4 (Reciproc Blue): instrumented and filled teeth with the presence of SI size 3 mm (n = 5); Group 5 (Reciproc Blue): instrumented and filled teeth with the presence of SI size 2 mm (n = 5); Group 6 (Protaper Next): instrumented and filled teeth with the presence of SI size 3 mm (n = 5); Group 7 (Protaper Next): instrumented and filled teeth with the presence of SI size 2 mm (n = 5).

#### *Imaging procedure*

To replicate the effect of soft tissue, the sample was placed in a mandible covered with a 5 mm thick layer of pink wax No. 7. During the CBCT examination, the mandible was placed in a rectangular Styrofoam box filled with water<sup>13,14</sup>. The teeth were positioned in the mandibular molar sockets #36 and #46, according to the side of the tooth assessed (right or left).

CBCT examinations were acquired using the KAVO OP 3D PRO device (Kavo Kerr, São Paulo-SP, Brazil), which operates with a 16-bit gray scale, and fixed tube voltage of 90 kVp. All CBCT scans were acquired in Endo mode: 85 µm voxel size with 8.7 seconds exposure time, a 5 × 5 cm FOV and, mA settings varying from 6.3, 7.0, 8.0, to 9.0 in Endo mode. Following image acquisition, all CBCT scans were exported in DICOM (Digital Imaging and Communications in Medicine) format (Figure 1).

#### *Image assessment*

The images were randomized using a random number generator without repetition (<https://www.invertexto.com/numeros-aleatorios>), and each image was assigned a unique code. Three experts in oral and maxillofacial radiology, with six years of experience in CBCT



examination, assessed the volumetric images using a 24-inch monitor (Philips D-Clinical, Amsterdam, Netherlands) with a resolution of  $1360 \times 768$  with Core i7 processor, 32GB of RAM, a 480GB SSD, and an 8GB GeForce 1070 graphics card computer. All assessments were done in a quiet room with dimmed light. The software used for the CBCT examination was OnDemand 3D™ (CyberMed Corporation, East Brunswick, United States). All observers were blinded to the study methodology.

Examiners assessed mesiobuccal canals qualitatively for the presence or absence of a SI using a 5-point scale (1 = absent, 2 = probably absent, 3 = uncertain, 4 = probably present, 5 = present), without being informed about the number of teeth with SI<sup>15,16</sup>.

Each examiner underwent training involving random volume examples (five CBCT examinations), that were not part of the sample, and an explanation of the intended identifications in the CBCT examination. Inter-observer and intra-observer agreement were calculated using 30% of the CBCT examinations.

### *Statistical analysis*

Data were analyzed using MedCalc (version 22.0, MedCalc Software Ltd., Ostend, Belgium). Intra- and inter-observer agreements were assessed using the weighted Kappa index, with interpretation based on the Landis and Koch scale<sup>17</sup>. Diagnostic metrics, including the area under the receiver operating characteristic curve (Az), sensitivity, and specificity for detecting SI, were evaluated for CBCT assessment method and according to different study factors. A multi-way ANOVA with Tukey post-hoc tests was used to compare results based on study factors (tube current level, instrument size, and endodontic file system). A significance level of 5% was used for all analyses.

## **Results**

The intraobserver agreement was moderate to excellent (0.47–0.81), and interobserver agreement (0.23–0.63) was considerable to substantial.

The identification of the WaveOne® Gold instrument at 3 mm size was significantly higher than the others SI evaluated in Az, at all tube currents evaluated ( $p < 0.05$ ). In contrast, the Protaper® Next 3 mm instrument had the worst sensitivity values, in all tube currents evaluated ( $p < 0.05$ ).

## **Discussion**

This study aimed to investigate the performance of evaluators in identifying SI, according to four different tube currents. A better Az average was observed in the identification of the WaveOne® Gold size 2 mm instrument, in three tube currents (6.3, 8.0, and 9.0 mA). Furthermore, the same instrument obtained the best Az averages at size 3 mm, in all tube currents evaluated ( $p < 0.05$ ). Carrying out this study was important, as it was identified that the type of instrument influences its detection. Furthermore, when checking different current tubes, it was observed that they have similar averages for identifying the SI, therefore it is preferable to use smaller current tubes.

The introduction of CBCT provides a three-dimensional assessment of oral structures in addition to periapical radiographs. In Endodontics, the most common format is a limited FOV volume in the form of a cylinder with approximately 40 to 50 mm in diameter depending on the manufacturer. This format provides for the imaging of approximately 4 teeth in the posterior and 6 teeth in the anterior area, ideal for most endodontic diagnostic, treatment planning, and problem-solving tasks. Limited FOV volumes allow for high-resolution scans with minimal distortion, an important aspect considering the minute details necessary to assess in Endodontics<sup>7</sup>. Therefore, a 5 x 5 cm FOV was used in this study.

However, one of the main limitations of CBCT is the formation of artifacts. The metallic composition of endodontic instruments generates image artefacts, which when associated with the artefacts produced by root filling materials, may impair the detection of SI<sup>18</sup>. The intensity of beam-hardening artifacts depends on the density of the materials present in the scanned area<sup>20</sup>. Previous studies have investigated the presence of different intracanal materials in the formation of artifacts in CBCT<sup>14,19,20</sup>.

One of the materials investigated by Lima et al.<sup>14</sup> was gutta-percha, which presented a large amount of hyperdense and hypodense artifacts when present in the vestibular and lingual roots of bi-rooted premolars, followed only by metal posts. Similarly, Marinho-Vieira et al.<sup>19</sup>, when investigating the influence of artifact formation on vertical root fractures detection, observed that when gutta-percha was present in both roots, moderate artifact interference was observed. In this study, the diagnostic task was impaired, and when there was moderate interference from the evaluators, the detection of root fracture was erroneous in most cases.

In addition to the types of artifacts mentioned above, blooming or volumetric distortion, defined as the type of artifact that causes volumetric changes in objects composed of high-density materials, not reliably increasing their dimensions in the reconstructed images, can also impair the assessment of endodontically filed teeth<sup>21</sup>. In the study by Coelho-Silva et al.<sup>22</sup>, aiming to evaluate whether dimensional changes occur in CBCT, using five types of

materials, including gutta-percha, it was observed that gutta-percha presented shape distortion in the Y-axis and the Z-axis ( $p < 0.05$ ). This shape distortion may affect the detection of SI, even if they are positioned in the vicinity of the root canal.

The commercially available gutta-percha cones are composed of organic (waxes, resins, and gutta-percha) and inorganic (barium sulfate and zinc oxide) materials. Barium sulfate ( $Z = 56$ ) and zinc oxide ( $Z = 30$ ) concentrations are directly related to gutta-percha's radiopacity and its artifact formation<sup>14</sup>. In the present study, a gutta-percha without barium sulfate in its composition was used<sup>23</sup>. The reason for its choice was to standardize the gutta-percha used for all teeth, regardless of the SI used.

Endodontic cements also have radiopacity, which may interfere on artifact formation<sup>20</sup>. Zinc-phosphate sealers present higher hyperdense artifact intensity than the resin sealer; however, endodontic cements represent a thin layer of material used in endodontic filling and post casting cementation techniques, which may not be enough to interfere with the overall artifact intensity of the resulting treatment.

In the present study, it was observed that the 3mm size WaveOne® Gold 3 mm SI files showed the best AZ values and similar sensitivity values in all tube currents. Therefore, low mA values can be used to detect SI files with the benefit of reducing the radiation dose to which the patient is exposed. Furthermore, according to Freitas et al.<sup>20</sup>, there is a lower production of artifacts at lower tube currents. In their study, Freitas et al.<sup>20</sup>, when investigating artifact formation using 6.3 and 10 mA, more hypodense halos, hypodense lines, and hyperdense lines were observed at 10 mA than at 6.3 mA ( $p < 0.05$ ).

Some CBCT scanners have fixed parameters settings, so voxel size, kVp, mA, exposure time and FOV may not be individually changed. The CBCT scanner used in this study has a fixed kVp setting and the possibility to vary other exposure parameters; however, for endodontic tasks, the manufacture advises the use of the Endo mode. The OP3D Endo mode setting allows you to use the smallest voxel size available (85µm) with fixed kVp (90), FOV (5x5 cm)

It is also noteworthy that current guidelines for the use of CBCT emphasize the balance between ionizing radiation dose and benefits in patient outcomes, adhering to the principles of limiting exposure to levels "as low as reasonably achievable" (ALARA) or "as low as diagnostically acceptable" (ALADA)<sup>4</sup>. Furthermore, the goal is to utilize the minimum radiation dose required to achieve adequate image quality for the specific diagnostic task in the specific patient, also, adhering to the principle "As Low As Diagnostically Achievable Being Indication-Oriented and Patient-Specific" (ALADAIP)<sup>24</sup>.

WaveOne® Gold and Reciproc® Blue instruments have a titanium oxide layer on their composition. The thickness of Reciproc® Blue titanium layer ranges between 60 and 80 nm while the thickness of WaveOne® Gold ranges between 100 and 140 nm<sup>25</sup>. The fact that WaveOne® Gold titanium layer is thicker may be the reason why it presented better Az results than the other studied SI. However, overall the specificity values were relatively low, except for the 9 mA setting, which indicates a difficulty in identifying the absence of the SI in CBCT scans.

The present study was the first to investigate the performance in detecting SI on fully endodontically filled mandibular molar canals using CBCT with varying tube currents. Despite this, the study sample was small, and further studies with larger samples, also using other types of endodontic instruments, sealers, and different CBCT scanners are needed to better assess this topic. Furthermore, it presents limitations typical of an ex vivo study, where it is not possible to fully mimic a clinical situation.

## Conclusion

Within the limitations of this study, it can be concluded that WaveOne® Gold SI can be better assessed in CBCT images than Reciproc® Blue and Protaper® Next, regardless of the chosen tube current. Therefore, in cases of suspected presence of SI, the use of lower tube currents is recommended.

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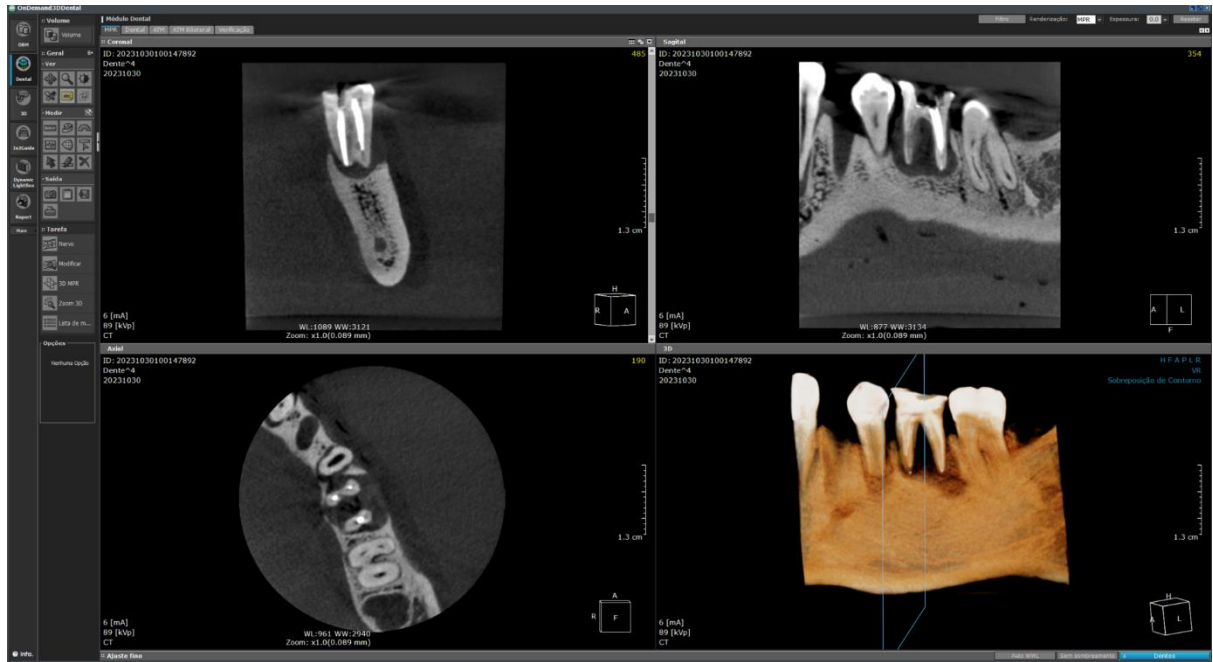
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**Figure captions**

**Figure 1.** Visualization of CBCT examination.





**Table 2.** Mean (standard deviation) values of area under the ROC curve (Az), sensitivity, and specificity for detecting separated endodontic instruments on CBCT Scans, based on tube

| Tube Current | Size | System         | Az                        | Sensitivity              | Specificity               |
|--------------|------|----------------|---------------------------|--------------------------|---------------------------|
|              |      |                | Mean (SD)                 |                          |                           |
| 6.3 mA       | 2 mm | WaveOne® Gold  | 0.68 (0.06) <sup>A*</sup> | 0.67 (0.23) <sup>A</sup> | 0.723 (0.25) <sup>A</sup> |
|              |      | Reciproc® Blue | 0.65 (0.06) <sup>A</sup>  | 0.67 (0.42) <sup>A</sup> | 0.67 (0.33) <sup>A</sup>  |
|              |      | Protaper® Next | 0.58 (0.07) <sup>A</sup>  | 0.53 (0.50) <sup>A</sup> | 0.67 (0.33) <sup>A</sup>  |
|              | 3 mm | WaveOne® Gold  | 0.81 (0.11) <sup>A</sup>  | 0.93 (0.11) <sup>A</sup> | 0.67 (0.33) <sup>A</sup>  |
|              |      | Reciproc® Blue | 0.67 (0.15) <sup>B</sup>  | 0.60 (0.53) <sup>A</sup> | 0.75 (0.22) <sup>A</sup>  |
|              |      | Protaper® Next | 0.56 (0.06) <sup>B</sup>  | 0.53 (0.50) <sup>B</sup> | 0.67 (0.33) <sup>A</sup>  |
|              | 2 mm | WaveOne® Gold  | 0.62 (0.07) <sup>A</sup>  | 0.53 (0.31) <sup>A</sup> | 0.72 (0.25) <sup>A</sup>  |
|              |      | Reciproc® Blue | 0.66 (0.05) <sup>A</sup>  | 0.47 (0.31) <sup>A</sup> | 0.86 (0.17) <sup>A</sup>  |
|              |      | Protaper® Next | 0.50 (0.006) <sup>A</sup> | 0.27 (0.45) <sup>A</sup> | 0.64 (0.49) <sup>A</sup>  |
|              | 3 mm | WaveOne® Gold  | 0.80 (0.04) <sup>A*</sup> | 0.87 (0.23) <sup>A</sup> | 0.72 (0.25) <sup>A</sup>  |
|              |      | Reciproc® Blue | 0.65 (0.13) <sup>B</sup>  | 0.60 (0.53) <sup>A</sup> | 0.72 (0.25) <sup>A</sup>  |
|              |      | Protaper® Next | 0.55 (0.08) <sup>B</sup>  | 0.27 (0.46) <sup>B</sup> | 0.78 (0.25) <sup>A</sup>  |
| 8.0 mA       | 2 mm | WaveOne® Gold  | 0.59 (0.08) <sup>A*</sup> | 0.47 (0.50) <sup>A</sup> | 0.72 (0.41) <sup>A</sup>  |
|              |      | Reciproc® Blue | 0.67 (0.13) <sup>A</sup>  | 0.73 (0.46) <sup>A</sup> | 0.75 (0.43) <sup>A</sup>  |
|              |      | Protaper® Next | 0.63 (0.03) <sup>A</sup>  | 0.53 (0.31) <sup>A</sup> | 0.72 (0.25) <sup>A</sup>  |
|              | 3 mm | WaveOne® Gold  | 0.85 (0.08) <sup>A</sup>  | 0.87 (0.11) <sup>A</sup> | 0.75 (0.22) <sup>A</sup>  |
|              |      | Reciproc® Blue | 0.60 (0.11) <sup>B</sup>  | 0.53 (0.46) <sup>A</sup> | 0.72 (0.25) <sup>A</sup>  |
|              |      | Protaper® Next | 0.59 (0.06) <sup>B</sup>  | 0.33 (0.42) <sup>B</sup> | 0.81 (0.27) <sup>A</sup>  |
|              | 2 mm | WaveOne® Gold  | 0.68 (0.13) <sup>A*</sup> | 0.47 (0.31) <sup>A</sup> | 0.92 (0.08) <sup>A</sup>  |
|              |      | Reciproc® Blue | 0.68 (0.24) <sup>A</sup>  | 0.60 (0.53) <sup>A</sup> | 0.78 (0.25) <sup>A</sup>  |
|              |      | Protaper® Next | 0.59 (0.03) <sup>A</sup>  | 0.53 (0.42) <sup>A</sup> | 0.67(0.44) <sup>A</sup>   |
|              | 3 mm | WaveOne® Gold  | 0.81 (0.13) <sup>A</sup>  | 0.67 (0.31) <sup>A</sup> | 0.92 (0.08) <sup>A</sup>  |
|              |      | Reciproc® Blue | 0.62 (0.18) <sup>B</sup>  | 0.47 (0.42) <sup>A</sup> | 0.78 (0.25) <sup>A</sup>  |
|              |      | Protaper® Next | 0.55 (0.06) <sup>B</sup>  | 0.13 (0.23) <sup>B</sup> | 0.89 (0.10) <sup>A</sup>  |

current (mA), instrument size, and endodontic file system.

Different uppercase letters indicate statistically significant differences among the endodontic file systems within each tube current level and endodontic instrument size for each accuracy metric ( $p < 0.05$ ).

Asterisk (\*) indicates a statistically significant difference among the endodontic instrument sizes within each tube current level and endodontic file system ( $p < 0.05$ ).

## CONSIDERAÇÕES FINAIS

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## 5 CONSIDERAÇÕES FINAIS

O presente estudo possui limitações características de estudos *ex vivo*, pois não é possível mimetizar completamente as condições de um organismo vivo. Contudo, foi utilizada uma mandíbula e dentes humanos, com *phantom*, tentando reproduzir ao máximo os tecidos orais. Dentro das limitações desse estudo, foi possível concluir que o método diagnóstico mais indicado na detecção de instrumentos endodônticos fraturados é a RPD. Além disso, realizar três incidências foi melhor do que uma, porém, se o diagnóstico for possível com um número menor de radiografias, não há necessidade de mais, visando reduzir a dose ao paciente. Além disso, o tipo de lima pode influenciar sua detecção, dependendo do método diagnóstico utilizado.

Com relação à TCFC, pode-se concluir que a WaveOne® Gold SI pode ser melhor avaliado, independentemente da corrente de tubo escolhida. Portanto, em casos de suspeita de presença de instrumento endodôntico fraturado, recomenda-se o uso de correntes de tubo mais baixas.

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## APÊNDICES

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## APÊNDICE A – TERMO DE DOAÇÃO DOS DENTES



UNIVERSIDADE ESTADUAL DA PARAÍBA  
COMITÊ DE ÉTICA EM PESQUISA

### TERMO DE DOAÇÃO DE DENTES

Ao Comitê de Ética em Pesquisa da Universidade Estadual da Paraíba,

Declaro que doei 90 (noventa) dentes molares inferiores aos pesquisadores Diego Pilipe Bezerra Silva e Daniela Pita de Melo a fins de viabilizar a execução da pesquisa intitulada “Comparação da acurácia da tomografia computadorizada de feixe cônico e radiografia periapical digital na detecção de instrumentos endodônticos fraturados em molares inferiores: um estudo *ex vivo*”. Também declaro que estes dentes foram extraídos previamente ao conhecimento da pesquisa supracitada, por indicação clínica e independentemente da mesma, sendo armazenados em frasco único, o que impossibilita a identificação dos indivíduos dos quais os dentes foram extraídos.

Campina Grande, 15 de março de 2023.

A handwritten signature in dark ink, reading 'Jussara da Silva Barbosa', is positioned above a horizontal line.

Jussara da Silva Barbosa

CPF: 099.115.414-28

CRO: 6379

Avante Odontologia - R. Odilon Almeida Barreto, 11, Queimadas - PB, 58475-000

Telefone: (83) 99116.2018

**APÊNDICE B – DECLARAÇÃO DE EMPRÉSTIMO DA MANDÍBULA SECA**

  
**UEPB**  
UNIVERSIDADE ESTADUAL DA PARAÍBA  
CAMPUS VIII – PROFª MARIA DA PENHA  
CENTRO DE CIÊNCIAS, TECNOLOGIA E SAÚDE

**DECLARAÇÃO**

Para os fins que forem necessários a Direção do Centro de Ciências, Tecnologia e Saúde – CCTS da UEPB informa que a profa. **Ana Marly Maia** foi autorizada para retirar do Laboratório de Morfologia do Curso de Odontologia do Campus VIII/UEPB peças anatômicas (ossos do crânio e face) para fins de pesquisa no Programa de Pós-Graduação em Odontologia da UEPB/Campus I.

Arauna - PB, 31 de outubro de 2016.

Atenciosamente,

  
**Manuel A. Gordón**  
Diretor CCTS  
UEPB Matr. 8255846  
**Manuel A. Gordón-Núñez**  
Diretor do Centro de Ciências, Tecnologia e Saúde  
Universidade estadual da Paraíba  
Matr. 825584-6

**ÁREA DE TRANSFERÊNCIA**

**PÁGINA INICIAL**    **INSERIR**    **LAYOUT DA PÁGINA**    **FÓRMULAS**    **DADOS**    **REVISÃO**    **EXIBIÇÃO**    **SUPLEMENTOS**    **Entrar**

**Fontes:** Calibri, 11, A, A, N, I, S, U, L, B, X, Y, Z, A-Z, a-z, 0-9, +, -, =, <, >, %, @, #, \$, €, £, ¥, ¢, ¤, ¨, °, ´, `

**Alinhamento:** Quebrar Texto Automaticamente, Mesclar e Centralizar

**Estilo:** Formatação Condicional, Formatar como Tabela, Célula

**Células:** Inserir, Excluir, Formatar

**Edição:** Classificar e Filtrar, Localizar e Selecionar

| A  | B     | C      | D  | E       | F    | G    | H    | I | J | K | L | M | N | O                        |
|----|-------|--------|----|---------|------|------|------|---|---|---|---|---|---|--------------------------|
| 1  | Dente | Código | mA | Tamanho | AV 1 | AV 2 | AV 3 |   |   |   |   |   |   |                          |
| 2  | 1     | 1145   | 1  | 1       |      |      |      |   |   |   |   |   | 1 | Definitivamente ausente  |
| 3  | 1     | 7960   | 1  | 1       |      |      |      |   |   |   |   |   | 2 | Provavelmente ausente    |
| 4  | 1     | 9574   | 1  | 1       |      |      |      |   |   |   |   |   | 3 | Incerto                  |
| 5  | 1     | 8225   | 1  | 1       |      |      |      |   |   |   |   |   | 4 | Provavelmente presente   |
| 6  | 2     | 1546   | 1  | 1       |      |      |      |   |   |   |   |   | 5 | Definitivamente presente |
| 7  | 2     | 8366   | 1  | 1       |      |      |      |   |   |   |   |   |   |                          |
| 8  | 2     | 7639   | 1  | 1       |      |      |      |   |   |   |   |   |   |                          |
| 9  | 2     | 3052   | 1  | 1       |      |      |      |   |   |   |   |   |   |                          |
| 10 | 3     | 9231   | 1  | 1       |      |      |      |   |   |   |   |   |   |                          |
| 11 | 3     | 6838   | 1  | 1       |      |      |      |   |   |   |   |   |   |                          |
| 12 | 3     | 5046   | 1  | 1       |      |      |      |   |   |   |   |   |   |                          |
| 13 | 3     | 2122   | 1  | 1       |      |      |      |   |   |   |   |   |   |                          |
| 14 | 4     | 6842   | 1  | 1       |      |      |      |   |   |   |   |   |   |                          |
| 15 | 4     | 2020   | 1  | 1       |      |      |      |   |   |   |   |   |   |                          |
| 16 | 4     | 1668   | 1  | 1       |      |      |      |   |   |   |   |   |   |                          |
| 17 | 4     | 6198   | 1  | 1       |      |      |      |   |   |   |   |   |   |                          |
| 18 | 5     | 4914   | 1  | 1       |      |      |      |   |   |   |   |   |   |                          |
| 19 | 5     | 8135   | 1  | 1       |      |      |      |   |   |   |   |   |   |                          |
| 20 | 5     | 6841   | 1  | 1       |      |      |      |   |   |   |   |   |   |                          |

**Legenda**

| mA | Score                    |
|----|--------------------------|
| 1  | Definitivamente ausente  |
| 2  | Provavelmente ausente    |
| 3  | Incerto                  |
| 4  | Provavelmente presente   |
| 5  | Definitivamente presente |

**Tipo**

| Tipo            |
|-----------------|
| 1 Sem lima      |
| 2 WaveOne Gold  |
| 3 Reciproc Blue |
| 4 Protaper Next |

**Tamanho**

| Tamanho |
|---------|
| 1 0 mm  |
| 2 2 mm  |
| 3 3 mm  |

## APÊNDICE D - PLANILHA COM PREENCHIMENTO DAS VARIÁVEIS INCLUÍDAS DAS AQUISIÇÕES FEITAS COM OS APARELHOS E SENSORES DE RADIOGRAFIA PERIAPICAL DIGITAL

| ARQUIVO                                                                           |  |  |  |  |  |  |  |  |  |  |  |  |  | PÁGINA INICIAL |  |  |  |  |  |  |  |  |  |  |  |  |  | INSERIR     |  |  |  |  |  |  |  |  |  |  |  |  |  | LAYOUT DA PÁGINA              |  |  |  |  |  |  |  |  |  |  |  |  |  | FÓRMULAS                                                                          |  |  |  |  |  |  |  |  |  |  |  |  |  | DADOS                                                                             |  |  |  |  |  |  |  |  |  |  |  |  |  | REVISÃO                       |  |  |  |  |  |  |  |  |  |  |  |  |  | EXIBIÇÃO |  |  |  |  |  |  |  |  |  |  |  |  |  | SUPLEMENTOS                                                                         |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
|-----------------------------------------------------------------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|----------------|--|--|--|--|--|--|--|--|--|--|--|--|--|-------------|--|--|--|--|--|--|--|--|--|--|--|--|--|-------------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|-----------------------------------------------------------------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|-----------------------------------------------------------------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|-------------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|----------|--|--|--|--|--|--|--|--|--|--|--|--|--|-------------------------------------------------------------------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|--------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|-------------------------|--|--|--|--|--|--|--|--|--|--|--|--|--|----------|--|--|--|--|--|--|--|--|--|--|--|--|--|---|--|--|--|--|--|--|--|--|--|--|--|--|--|
|  |  |  |  |  |  |  |  |  |  |  |  |  |  | Calibri        |  |  |  |  |  |  |  |  |  |  |  |  |  | 11          |  |  |  |  |  |  |  |  |  |  |  |  |  | A <sup>+</sup> A <sup>-</sup> |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Quebrar Texto Automaticamente |  |  |  |  |  |  |  |  |  |  |  |  |  | Geral    |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | Formato Condicional      |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Área de Transf...                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | Fonte          |  |  |  |  |  |  |  |  |  |  |  |  |  | Alinhamento |  |  |  |  |  |  |  |  |  |  |  |  |  | Número                        |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  |                               |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A1                                                                                |  |  |  |  |  |  |  |  |  |  |  |  |  | Dente          |  |  |  |  |  |  |  |  |  |  |  |  |  |             |  |  |  |  |  |  |  |  |  |  |  |  |  |                               |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  |                               |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| A                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | B              |  |  |  |  |  |  |  |  |  |  |  |  |  | C           |  |  |  |  |  |  |  |  |  |  |  |  |  | D                             |  |  |  |  |  |  |  |  |  |  |  |  |  | E                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | F                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | G                             |  |  |  |  |  |  |  |  |  |  |  |  |  | H        |  |  |  |  |  |  |  |  |  |  |  |  |  | I                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  | J                        |  |  |  |  |  |  |  |  |  |  |  |  |  | K                       |  |  |  |  |  |  |  |  |  |  |  |  |  | L        |  |  |  |  |  |  |  |  |  |  |  |  |  | M |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1 Dente                                                                           |  |  |  |  |  |  |  |  |  |  |  |  |  | Código         |  |  |  |  |  |  |  |  |  |  |  |  |  | Tipo        |  |  |  |  |  |  |  |  |  |  |  |  |  | Incidência                    |  |  |  |  |  |  |  |  |  |  |  |  |  | Tamanho                                                                           |  |  |  |  |  |  |  |  |  |  |  |  |  | Aparelho                                                                          |  |  |  |  |  |  |  |  |  |  |  |  |  | Sensor                        |  |  |  |  |  |  |  |  |  |  |  |  |  | AV1      |  |  |  |  |  |  |  |  |  |  |  |  |  | AV2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | AV3                      |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  | Legenda  |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 2 1                                                                               |  |  |  |  |  |  |  |  |  |  |  |  |  | 9241           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1        |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  | Aparelho |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 3 1                                                                               |  |  |  |  |  |  |  |  |  |  |  |  |  | 9733           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  |                               |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                        |  |  |  |  |  |  |  |  |  |  |  |  |  | Kavo                    |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 4 1                                                                               |  |  |  |  |  |  |  |  |  |  |  |  |  | 2704           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                       |  |  |  |  |  |  |  |  |  |  |  |  |  | Diox     |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 5 1                                                                               |  |  |  |  |  |  |  |  |  |  |  |  |  | 3551           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  | Tipo                    |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 6 1                                                                               |  |  |  |  |  |  |  |  |  |  |  |  |  | 8141           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 7 1                                                                               |  |  |  |  |  |  |  |  |  |  |  |  |  | 9702           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 8 1                                                                               |  |  |  |  |  |  |  |  |  |  |  |  |  | 9541           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                        |  |  |  |  |  |  |  |  |  |  |  |  |  | Sem lima                |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 9 1                                                                               |  |  |  |  |  |  |  |  |  |  |  |  |  | 8423           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                        |  |  |  |  |  |  |  |  |  |  |  |  |  | WaveOne Gold            |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 10 2                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 5837           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  | 3                        |  |  |  |  |  |  |  |  |  |  |  |  |  | Reciproc Blue           |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 11 2                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 7363           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  | 4                        |  |  |  |  |  |  |  |  |  |  |  |  |  | Protaper Next           |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 12 2                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 4616           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  | Tamanho                  |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 13 2                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 3549           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  | 0 mm                    |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 14 2                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 7902           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  | 2 mm                    |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 15 2                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 1803           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  | 3                        |  |  |  |  |  |  |  |  |  |  |  |  |  | 3 mm                    |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 16 2                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 1833           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  | Sensor                   |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 17 2                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 3941           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  | RVG                     |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 18 3                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 6513           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  | Microimagem             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 19 3                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 3653           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  | Incidência               |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 20 3                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 9490           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  | Ortorradial             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 21 3                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 8601           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  | Orto, mesio, disto      |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 22 3                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 7083           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  | Score                    |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 23 3                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 9413           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |                                                                                     |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 24 3                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 7258           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  |                          |  |  |  |  |  |  |  |  |  |  |  |  |  | Definitivamente ausente |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 25 3                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 4895           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  | Provavelmente ausente    |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 26 4                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 5781           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  | 3                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  | Incerto                  |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 27 4                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 2456           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  | 4                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  | Provavelmente presente   |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 28 4                                                                              |  |  |  |  |  |  |  |  |  |  |  |  |  | 6600           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1           |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                             |  |  |  |  |  |  |  |  |  |  |  |  |  | 1                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                                                                                 |  |  |  |  |  |  |  |  |  |  |  |  |  | 2                             |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  | 5                                                                                   |  |  |  |  |  |  |  |  |  |  |  |  |  | Definitivamente presente |  |  |  |  |  |  |  |  |  |  |  |  |  |                         |  |  |  |  |  |  |  |  |  |  |  |  |  |          |  |  |  |  |  |  |  |  |  |  |  |  |  |   |  |  |  |  |  |  |  |  |  |  |  |  |  |



## ANEXO A – PARECER DO COMITÊ DE ÉTICA EM PESQUISA DA UEPB

UNIVERSIDADE ESTADUAL DA  
PARAÍBA - PRÓ-REITORIA DE  
PÓS-GRADUAÇÃO E  
PESQUISA - UEPB / PRPGP



### PARECER CONSUBSTANCIADO DO CEP

#### DADOS DO PROJETO DE PESQUISA

**Título da Pesquisa:** COMPARAÇÃO DA ACURÁCIA DA TOMOGRAFIA COMPUTADORIZADA DE FEIXE CÔNICO E RADIOGRAFIA PERIAPICAL DIGITAL NA DETECÇÃO DE INSTRUMENTOS ENDODÔNTICOS FRATURADOS EM MOLARES INFERIORES:

**Pesquisador:** Diego Filipe Bezerra Silva

**Área Temática:**

**Versão:** 2

**CAAE:** 68420423.4.0000.5187

**Instituição Proponente:** Universidade Estadual da Paraíba - UEPB

**Patrocinador Principal:** Financiamento Próprio

#### DADOS DO PARECER

**Número do Parecer:** 6.026.095

#### Apresentação do Projeto:

A pesquisa a ser desenvolvida consistirá em um estudo do tipo experimental, laboratorial ex vivo. A seleção e preparo das amostras serão realizados no Laboratório de Dentística, Prótese Dentária e Endodontia da Universidade Estadual da Paraíba (UEPB), Campus I. A aquisição das imagens periapicais digitais e tomográficas será realizada no setor de Radiologia do Departamento de Odontologia da instituição reitada anteriormente. A população objeto do presente estudo será constituída por dentes molares inferiores provenientes de exodontias, dos quais serão realizados tratamento endodôntico com instalação de ímas fraturadas e aquisição de imagens radiográficas periapicais digitais e tomográficas.

#### Objetivo da Pesquisa:

##### GERAL:

Comparar a acurácia, sensibilidade e especificidade de protocolos de imagem em TCFC e radiografias periapicais digitais na identificação de diferentes instrumentos endodônticos fraturados em canais radiculares obturados de dentes molares inferiores.

##### ESPECÍFICOS:

Avaliar e comparar a detecção de instrumentos rotatórios fraturados em canais radiculares por meio de radiografias periapicais e TCFC:

Endereço: Av. das Banúas, 351 - Campus Universitário  
Bairro: Bodocanga CEP: 58.109-753  
UF: PB Município: CAMPINA GRANDE  
Telefone: (83)3315-3373 Fax: (83)3315-3373 E-mail: cep@setor.uepb.edu.br



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Continuação do Parecer: 6.026.026

Verificar a influência dos parâmetros de exposição (mA e kV) da TCFC na detecção de instrumentos rotatórios fraturados:

Avaliar a influência do tipo e tamanho do instrumento fraturado (2 e 3 mm) no conduto radicular na detecção de instrumentos rotatórios fraturados em radiografias periapicais e TCFC.

**Avaliação dos Riscos e Benefícios:**

Os possíveis riscos durante a execução da metodologia proposta são de possível contaminação ou acidentes durante os preparos dentários. Esses riscos medianos, no entanto, todas as medidas de biossegurança serão realizadas com a utilização de equipamentos de proteção individual (EPI) e estenização dos dentes. Os benefícios esperados, são o fornecimento ao clínico parâmetros necessários para escolha do melhor método de imagem para identificação de possíveis instrumentos fraturados nos canais radiculares, além da seleção do melhor parâmetro de exposição, no caso da TCFC.

**Comentários e Considerações sobre a Pesquisa:**

A proposta do projeto é relevante, uma vez que proporciona um avanço no conhecimento, com a possibilidade de trazer contribuição para que o clínico tenha segurança ao escolher o melhor método de imagem para identificação de possíveis instrumentos fraturados nos canais radiculares e na seleção e aplicação do melhor parâmetro de exposição para aumentar a acurácia da detecção do instrumento.

**Considerações sobre os Termos de apresentação obrigatória:**

Folha de rosto: anexada;

Autorização Institucional: Anexada

Declaração de concordância com projeto de pesquisa: anexado

Termo de Compromisso do Pesquisador Responsável: anexado

Termo de doação do dente: anexado

TCLE: não se aplica (devidamente justificado)

**Recomendações:**

O projeto é relevante, apresenta importância acadêmica e a metodologia está clara e adequada ao que se propõe. Todos os termos foram anexados.

**Conclusões ou Pendências e Lista de Inadequações:**

O projeto apresenta todos os documentos necessários, desta forma está aprovado salvo melhor

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Continuação do Parecer: 6.026.026

entendimento.

**Considerações Finais a critério do CEP:**

**Este parecer foi elaborado baseado nos documentos abaixo relacionados:**

| Tipo Documento                                            | Arquivo                                       | Postagem               | Autor                      | Situação |
|-----------------------------------------------------------|-----------------------------------------------|------------------------|----------------------------|----------|
| Informações Básicas do Projeto                            | PE_INFORMAÇÕES_BÁSICAS_DO_PROJETO_2107632.pdf | 10/04/2023<br>06:37:39 |                            | Acatado  |
| Projeto Detalhado / Brochura Investigador                 | Projeto_de_Pesquisa.docx                      | 10/04/2023<br>06:37:14 | Diego Filipe Bezerra Silva | Acatado  |
| Outros                                                    | Termo_de_Compromisso_Pesquisador_Resp.pdf     | 30/03/2023<br>22:03:42 | Diego Filipe Bezerra Silva | Acatado  |
| Outros                                                    | TAI_laboratorios.jpeg                         | 27/03/2023<br>18:30:37 | Diego Filipe Bezerra Silva | Acatado  |
| Outros                                                    | TAICDA.jpeg                                   | 27/03/2023<br>18:28:58 | Diego Filipe Bezerra Silva | Acatado  |
| Outros                                                    | TAI_Radiologia.jpeg                           | 27/03/2023<br>18:28:10 | Diego Filipe Bezerra Silva | Acatado  |
| Declaração de Pesquisadores                               | Termo_de_compromisso_pesquisadores.jpeg       | 27/03/2023<br>18:27:24 | Diego Filipe Bezerra Silva | Acatado  |
| Folha de Rosto                                            | FOLHADEROSTO1.pdf                             | 27/03/2023<br>18:26:08 | Diego Filipe Bezerra Silva | Acatado  |
| Outros                                                    | Termo_cranio_e_mandibula.pdf                  | 20/03/2023<br>19:17:38 | Diego Filipe Bezerra Silva | Acatado  |
| Outros                                                    | Termo_de_doacao_de_dentes.pdf                 | 20/03/2023<br>19:17:02 | Diego Filipe Bezerra Silva | Acatado  |
| TCLE / Termos de Assentimento / Justificativa de Ausência | TCLE.docx                                     | 20/03/2023<br>19:16:38 | Diego Filipe Bezerra Silva | Acatado  |
| Declaração de concordância                                | Declaracao_de_concordancia.pdf                | 20/03/2023<br>19:14:59 | Diego Filipe Bezerra Silva | Acatado  |

**Situação do Parecer:**

Aprovado

**Necessita Apreciação da CONEP:**

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Continuação do Parecer: 6.026.026

CAMPINA GRANDE, 27 de Abril de 2023

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Assinado por:  
Gabriela Maria Cavalcanti Costa  
(Coordenador(a))

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## ANEXO B – NORMAS PARA SUBMISSÃO DE ARTIGOS NO PERIÓDICO *CLINICAL ORAL INVESTIGATIONS*.

# Instructions for Authors

## Types of papers

Papers may be submitted for the following sections:

- 
- Research Article
- Reviews
- Brief Report – with up to 2000 words and up to two figures and/or tables
- Correspondence (Discussion paper)
- Debate (Letter to the Editor)
- Perspective (by Editor invitation only)  
 Perspective articles are focused articles on topics of interest to a broad audience, but are written from a personal viewpoint. They are intended to provide a forum to be more speculative than Reviews, but should remain balanced and are intended to cover timely and relevant topics. These articles are peer reviewed.  
 Limited to 1,500-3,000 words (excluding abstract, references and figure legends);  
 Unstructured abstract 200 words; 4 tables/figures; 60 references

It is the general policy of this journal not to accept case reports and pilot studies.

## Editorial Procedure

Clinical Oral Investigations operates a single-blind peer-review system, where the reviewers are aware of the names and affiliations of the authors, but the reviewer reports provided to authors are anonymous.

Submitted manuscripts will generally be reviewed by two or more experts who will be asked to evaluate whether the manuscript is scientifically sound and coherent, whether it duplicates already published work, and whether or not the manuscript is sufficiently clear for publication. The Editors will reach a decision based on these reports and, where necessary, they will consult with members of the Editorial Board.

## Summary of the editorial process

- 
- The author submits a manuscript and the Editorial Office performs an initial quality check on the manuscript to ensure that the paper is formatted correctly
- The manuscript receives a tracking number and Manuscripts are assigned to an Editor-in-Chief or a Section Editor for an initial editorial assessment. If the decision is not to send the manuscript for review, the Editor contacts the author with the decision.
- If the Editor decides the paper is within the Journal's remit, peer reviewers are selected and assigned. This can take some time dependent on the responsiveness and availability of the reviewers selected.
- Reviewers are given 14 days from acceptance to submit their reports. Once the required reports are submitted, the Associate Editor will give a recommendation or the Editor-in-Chief makes a final decision based on the comments received. The final decision is the sole responsibility of the Editors-in-Chief.

## Manuscript Submission

### Manuscript Submission

Submission of a manuscript implies: that the work described has not been published before; that it is not under consideration for publication anywhere else; that its publication has been approved by all co-authors, if any, as well as by the responsible authorities – tacitly or explicitly – at the institute where the work has been carried out. The publisher will not be held legally responsible should there be any claims for compensation.

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### Online Submission

Please follow the hyperlink “Submit manuscript” and upload all of your manuscript files following the instructions given on the screen.

### Source Files

Please ensure you provide all relevant editable source files at every submission and revision. Failing to submit a complete set of editable source files will result in your article not being considered for review. For your manuscript text please always submit in common word processing formats such as .docx or LaTeX.

### Submitting Declarations

Please note that [Author Contribution information](#) and [Competing Interest information](#) must be provided at submission via the submission interface. Only the information submitted via the interface will be used in the final published version. Please make sure that if you are an editorial board member and also a listed author that you also declare this information in the Competing Interest section of the interface.

Please see the relevant sections in the submission guidelines for further information on these statements as well as possible other mandatory statements.

### Further Useful Information

please follow the link below

[Further Useful Information](#)

The Springer Author Academy is a set of comprehensive online training pages mainly geared towards first-time authors. At this point, more than 50 pages offer advice to authors on how to write and publish a journal article.

[Springer Author Academy](#)

## Title Page

The title page should include:

- The name(s) of the author(s)
- A concise and informative title
- The affiliation(s) and address(es) of the author(s)
- The e-mail address, telephone and fax numbers of the corresponding author

## Abstract

Please provide a structured abstract of 150 to 250 words which should be divided into the following sections:

- Objectives (stating the main purposes and research question)
- Materials and Methods
- Results
- Conclusions
- Clinical Relevance

These headings must appear in the abstract.

## Keywords

Please provide 4 to 6 keywords which can be used for indexing purposes.

## Text

### Text Formatting

Manuscripts should be submitted in Word.

- Use a normal, plain font (e.g., 10-point Times Roman) for text.
- Use italics for emphasis.
- Use the automatic page numbering function to number the pages.
- Do not use field functions.
- Use tab stops or other commands for indents, not the space bar.
- Use the table function, not spreadsheets, to make tables.
- Use the equation editor or MathType for equations.
- Save your file in docx format (Word 2007 or higher) or doc format (older Word versions).

Manuscripts with mathematical content can also be submitted in LaTeX. We recommend using [Springer Nature's LaTeX template](#).

## Headings

Please use no more than three levels of displayed headings.

## Abbreviations

Abbreviations should be defined at first mention and used consistently thereafter.

## Footnotes

Footnotes can be used to give additional information, which may include the citation of a reference included in the reference list. They should not consist solely of a reference citation, and they should never include the bibliographic details of a reference. They should also not contain any figures or tables.

Footnotes to the text are numbered consecutively; those to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data). Footnotes to the title or the authors of the article are not given reference symbols. Always use footnotes instead of endnotes.

## Acknowledgments

Acknowledgments of people, grants, funds, etc. should be placed in a separate section on the title page. The names of funding organizations should be written in full.

## References

### Citation

Reference citations in the text should be identified by numbers in square brackets. Some examples:

1. Negotiation research spans many disciplines [3].
2. This result was later contradicted by Becker and Seligman [5].
3. This effect has been widely studied [1-3, 7].

### Reference list

The list of references should only include works that are cited in the text and that have been published or accepted for publication. Personal communications and unpublished works should only be mentioned in the text.

The entries in the list should be numbered consecutively.

If available, please always include DOIs as full DOI links in your reference list (e.g. “<https://doi.org/abc>”).

- Journal article  
Gamelin FX, Baquet G, Berthoin S, Thevenet D, Nourry C, Nottin S, Bosquet L (2009) Effect of high intensity intermittent training on heart rate variability in prepubescent children. *Eur J Appl Physiol* 105:731-738.  
<https://doi.org/10.1007/s00421-008-0955-8>  
Ideally, the names of all authors should be provided, but the usage of “et al” in long author lists will also be accepted:  
Smith J, Jones M Jr, Houghton L et al (1999) Future of health insurance. *N Engl J Med* 341:325–329
- Article by DOI  
Slifka MK, Whitton JL (2000) Clinical implications of dysregulated cytokine production. *J Mol Med.* <https://doi.org/10.1007/s001090000086>
- Book  
South J, Blass B (2001) *The future of modern genomics*. Blackwell, London
- Book chapter  
Brown B, Aaron M (2001) The politics of nature. In: Smith J (ed) *The rise of modern genomics*, 3rd edn. Wiley, New York, pp 230-257

- Online document  
Cartwright J (2007) Big stars have weather too. IOP Publishing PhysicsWeb.  
<http://physicsweb.org/articles/news/11/6/16/1>. Accessed 26 June 2007
- Dissertation  
Trent JW (1975) Experimental acute renal failure. Dissertation, University of California

Always use the standard abbreviation of a journal's name according to the ISSN List of Title Word Abbreviations, see

[ISSN.org LTWA](http://www.issn.org/LTWA)

If you are unsure, please use the full journal title.

Authors preparing their manuscript in LaTeX can use the bibliography style file sn-basic.bst which is included in the [Springer Nature Article Template](#).

## Tables

- All tables are to be numbered using Arabic numerals.
- Tables should always be cited in text in consecutive numerical order.
- For each table, please supply a table caption (title) explaining the components of the table.
- Identify any previously published material by giving the original source in the form of a reference at the end of the table caption.
- Footnotes to tables should be indicated by superscript lower-case letters (or asterisks for significance values and other statistical data) and included beneath the table body.

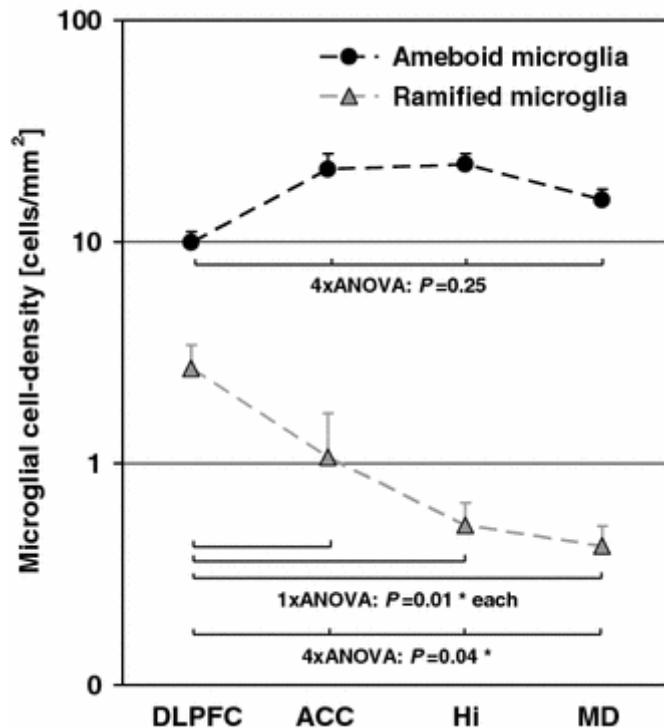
## Artwork and Illustrations Guidelines

### Electronic Figure Submission

- 
- Supply all figures electronically.
- Indicate what graphics program was used to create the artwork.
- For vector graphics, the preferred format is EPS; for halftones, please use TIFF format. MSOffice files are also acceptable.
- Vector graphics containing fonts must have the fonts embedded in the files.
- Name your figure files with "Fig" and the figure number, e.g., Fig1.eps.

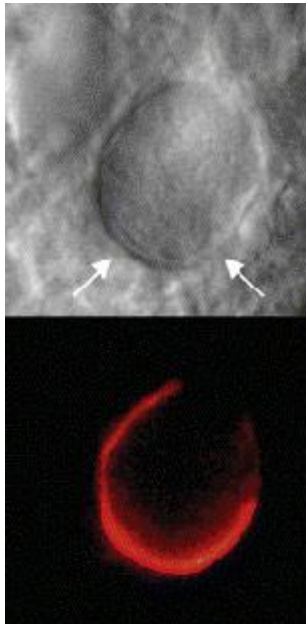
### Line Art





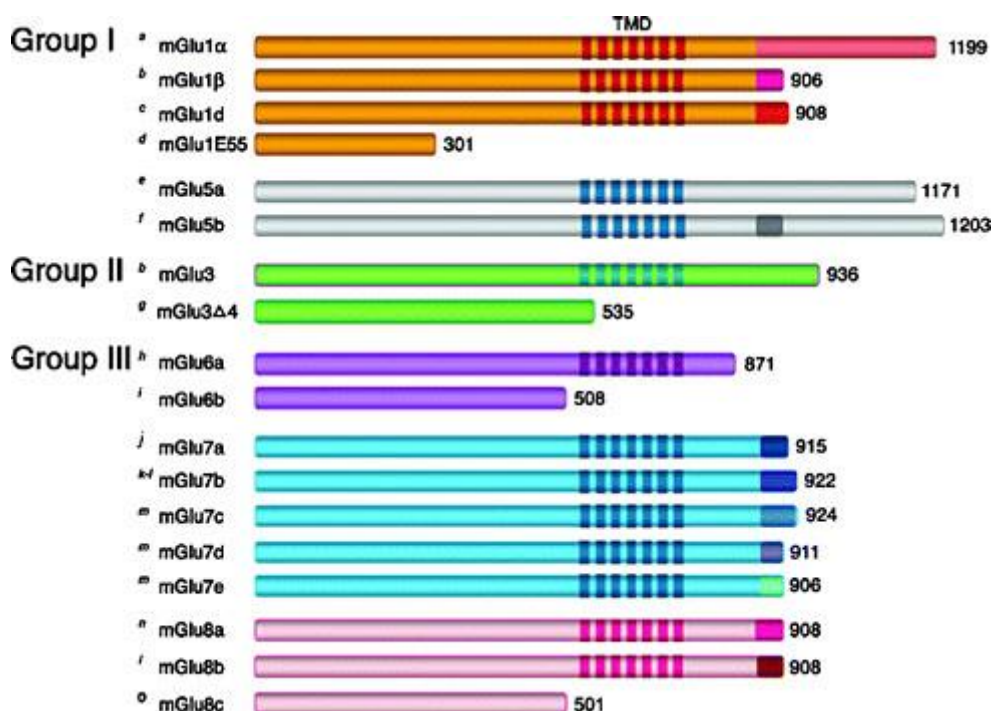
- Definition: Black and white graphic with no shading.
- Do not use faint lines and/or lettering and check that all lines and lettering within the figures are legible at final size.
- All lines should be at least 0.1 mm (0.3 pt) wide.
- Scanned line drawings and line drawings in bitmap format should have a minimum resolution of 1200 dpi.
- Vector graphics containing fonts must have the fonts embedded in the files.

### Halftone Art



- Definition: Photographs, drawings, or paintings with fine shading, etc.
- If any magnification is used in the photographs, indicate this by using scale bars within the figures themselves.
- Halftones should have a minimum resolution of 300 dpi.

### Combination Art



- Definition: a combination of halftone and line art, e.g., halftones containing line drawing, extensive lettering, color diagrams, etc.
- Combination artwork should have a minimum resolution of 600 dpi.

## Color Art

- 
- Color art is free of charge for online publication.
- If black and white will be shown in the print version, make sure that the main information will still be visible. Many colors are not distinguishable from one another when converted to black and white. A simple way to check this is to make a xerographic copy to see if the necessary distinctions between the different colors are still apparent.
- If the figures will be printed in black and white, do not refer to color in the captions.
- Color illustrations should be submitted as RGB (8 bits per channel).

## Figure Lettering

- 
- To add lettering, it is best to use Helvetica or Arial (sans serif fonts).
- Keep lettering consistently sized throughout your final-sized artwork, usually about 2–3 mm (8–12 pt).
- Variance of type size within an illustration should be minimal, e.g., do not use 8-pt type on an axis and 20-pt type for the axis label.
- Avoid effects such as shading, outline letters, etc.
- Do not include titles or captions within your illustrations.

## Figure Numbering

- All figures are to be numbered using Arabic numerals.
- Figures should always be cited in text in consecutive numerical order.
- Figure parts should be denoted by lowercase letters (a, b, c, etc.).
- If an appendix appears in your article and it contains one or more figures, continue the

consecutive numbering of the main text. Do not number the appendix figures, "A1, A2, A3, etc." Figures in online appendices [Supplementary Information (SI)] should, however, be numbered separately.

### **Figure Captions**

- Each figure should have a concise caption describing accurately what the figure depicts. Include the captions in the text file of the manuscript, not in the figure file.
- Figure captions begin with the term Fig. in bold type, followed by the figure number, also in bold type.
- No punctuation is to be included after the number, nor is any punctuation to be placed at the end of the caption.
- Identify all elements found in the figure in the figure caption; and use boxes, circles, etc., as coordinate points in graphs.
- Identify previously published material by giving the original source in the form of a reference citation at the end of the figure caption.

### **Figure Placement and Size**

- Figures should be submitted within the body of the text. Only if the file size of the manuscript causes problems in uploading it, the large figures should be submitted separately from the text.
- When preparing your figures, size figures to fit in the column width.
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- For small-sized journals, the figures should be 119 mm wide and not higher than 195 mm.

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- Patterns are used instead of or in addition to colors for conveying information (colorblind users would then be able to distinguish the visual elements)
- Any figure lettering has a contrast ratio of at least 4.5:1

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Springer accepts electronic multimedia files (animations, movies, audio, etc.) and other supplementary files to be published online along with an article or a book chapter. This feature can add dimension to the author's article, as certain information cannot be printed or is more convenient in electronic form.

Before submitting research datasets as Supplementary Information, authors should read the journal's Research data policy. We encourage research data to be archived in data repositories wherever possible.

### **Submission**

- Supply all supplementary material in standard file formats.
- Please include in each file the following information: article title, journal name, author names; affiliation and e-mail address of the corresponding author.
- To accommodate user downloads, please keep in mind that larger-sized files may require very long download times and that some users may experience other problems during downloading.
- High resolution (streamable quality) videos can be submitted up to a maximum of 25GB; low resolution videos should not be larger than 5GB.

### **Audio, Video, and Animations**

- Aspect ratio: 16:9 or 4:3
- Maximum file size: 25 GB for high resolution files; 5 GB for low resolution files
- Minimum video duration: 1 sec
- Supported file formats: avi, wmv, mp4, mov, m2p, mp2, mpg, mpeg, flv, mxf, mts, m4v, 3gp

### **Text and Presentations**

- Submit your material in PDF format; .doc or .ppt files are not suitable for long-term viability.
- A collection of figures may also be combined in a PDF file.

### **Spreadsheets**

- Spreadsheets should be submitted as .csv or .xlsx files (MS Excel).

### **Specialized Formats**

- Specialized format such as .pdb (chemical), .wrl (VRML), .nb (Mathematica notebook), and .tex can also be supplied.

### **Collecting Multiple Files**

- It is possible to collect multiple files in a .zip or .gz file.

### **Numbering**

- If supplying any supplementary material, the text must make specific mention of the material as a citation, similar to that of figures and tables.
- Refer to the supplementary files as “Online Resource”, e.g., “... as shown in the animation (Online Resource 3)”, “... additional data are given in Online Resource 4”.
- Name the files consecutively, e.g. “ESM\_3.mpg”, “ESM\_4.pdf”.

### **Captions**

- For each supplementary material, please supply a concise caption describing the content of the file.

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- Supplementary Information (SI) will be published as received from the author without any conversion, editing, or reformatting.

### **Accessibility**

In order to give people of all abilities and disabilities access to the content of your supplementary files, please make sure that

- The manuscript contains a descriptive caption for each supplementary material
- Video files do not contain anything that flashes more than three times per second (so that users prone to seizures caused by such effects are not put at risk)

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Please check [Springer’s policy on generative AI images](#) and make sure your work adheres to the principles described therein.

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## Recommended sites

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- 2) drafted the work or revised it critically for important intellectual content;
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\* Based on/adapted from:

[ICMJE, Defining the Role of Authors and Contributors, Transparency in authors' contributions and responsibilities to promote integrity in scientific publication, McNutt at all, PNAS February 27, 2018](#)

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## **Research involving human participants, their data or biological material**

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When reporting a study that involved human participants, their data or biological material, authors should include a statement that confirms that the study was approved (or granted exemption) by the appropriate institutional and/or national research ethics committee (including the name of the ethics committee) and certify that the study was performed in accordance with the ethical standards as laid down in the [1964 Declaration of Helsinki](#) and its later amendments or comparable ethical standards. If doubt exists whether the research was conducted in accordance with the 1964 Helsinki Declaration or comparable standards, the authors must explain the reasons for their approach, and demonstrate that an independent ethics committee or institutional review board explicitly approved the doubtful aspects of the study. If a study was granted exemption from requiring ethics approval, this should also be detailed in the manuscript (including the reasons for the exemption).

### **Retrospective ethics approval**

If a study has not been granted ethics committee approval prior to commencing, retrospective ethics approval usually cannot be obtained and it may not be possible to consider the manuscript for peer review. The decision on whether to proceed to peer review in such cases is at the Editor's discretion.

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Although retrospective studies are conducted on already available data or biological material (for which formal consent may not be needed or is difficult to obtain) ethics approval may be required dependent on the law and the national ethical guidelines of a country. Authors should check with their institution to make sure they are complying with the specific requirements of their country.

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**Plasmid:** mRuby3 plasmid **RRID:**Addgene\_104005

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The trial registration number (TRN) and date of registration should be included as the last line of the manuscript abstract.

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The above should be summarized in a statement and placed in a 'Declarations' section before the reference list under a heading of 'Ethics approval'.

Examples of statements to be used when ethics approval has been obtained:

- All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. The study was approved by the Bioethics Committee of the Medical University of A (No. ...).
- This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of University B (Date.../No. ...).
- Approval was obtained from the ethics committee of University C. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.
- The questionnaire and methodology for this study was approved by the Human Research Ethics committee of the University of D (Ethics approval number: ...).

Examples of statements to be used for a retrospective study:

- Ethical approval was waived by the local Ethics Committee of University A in view of the retrospective nature of the study and all the procedures being performed were part of the routine care.
- This research study was conducted retrospectively from data obtained for clinical purposes. We consulted extensively with the IRB of XYZ who determined that our study did not need ethical approval. An IRB official waiver of ethical approval was granted from the IRB of XYZ.
- This retrospective chart review study involving human participants was in accordance with the ethical standards of the institutional and national research committee and with the 1964

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[Back to top](#)

## **Informed consent**

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When biological material is donated for or data is generated as part of a research project authors should ensure, as part of the informed consent procedure, that the participants are



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Individuals may consent to participate in a study, but object to having their data published in a journal article. Authors should make sure to also seek consent from individuals to publish their data prior to submitting their paper to a journal. This is in particular applicable to case studies. A consent to publish form can be found

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### **Summary of requirements**

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Please see the various examples of wording below and revise/customize the sample statements according to your own needs.

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The authors affirm that human research participants provided informed consent for publication of the images in Figure(s) 1a, 1b and 1c.

The participant has consented to the submission of the case report to the journal.

Patients signed informed consent regarding publishing their data and photographs.

Sample statements if identifying information about participants is available in the article:

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Sex generally refers to a set of biological attributes that are associated with physical and physiological features (e.g., chromosomal genotype, hormonal levels, internal and external anatomy). A binary sex categorization (male/female) is usually designated at birth ("sex assigned at birth"), most often based solely on the visible external anatomy of a newborn. Gender generally refers to socially constructed roles, behaviors, and identities of women, men and gender-diverse people that occur in a historical and cultural context and may vary across societies and over time. Gender influences how people view themselves and each other, how they behave and interact and how power is distributed in society. Sex and gender are often

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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 develop the 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, that is, 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.

h. Authors should be aware that the JOE uses iThenticate, plagiarism detection software, to ensure originality and integrity of material published in the journal. The use of copied sentences, even when present within quotation marks, is highly discouraged. Instead, the information of the original research should be expressed by the new manuscript author’s own words, and a proper citation given at the end of the sentence. Plagiarism will not be tolerated and manuscripts will be rejected or papers withdrawn after publication based on unethical actions by the authors. In addition, authors may be sanctioned for future publication.

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To avoid unnecessary errors you are strongly advised to use the 'spell-check' and 'grammar-check' functions of your word processor.

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A structured abstract, by means of appropriate headings, should provide the context or background for the research and should state its purpose, basic procedures (selection of study subjects or laboratory animals, observational and analytical methods), main findings (giving specific effect sizes and their statistical significance, if possible), and principal conclusions. It should emphasize new and important aspects of the study or observations.

### Abstract Headings

Introduction, Methods, Results, Conclusions

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Immediately after the abstract, provide a maximum of 6 keywords, using American spelling and avoiding general and plural terms and multiple concepts (avoid, for example, 'and', 'of'). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes.

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Collate acknowledgements in a separate section at the end of the article before the references and do not, therefore, include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proof reading the article, etc.).

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The Abstract concisely describes the purpose of the study in 250 or fewer words. It must be organized into sections: Introduction, Methods, Results, and Conclusions. The hypothesis is described in the Abstract Introduction. The Abstract describes the new contributions made by this study. The Abstract word limitation and its wide distribution (eg, PubMed) make it challenging to write clearly. This section is written last by many authors. Write the abstract in past tense because the study has been completed. Provide 3-5 keywords.

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## Tables

Tables are appropriate when it is critical to present exact numeric values; however, not all results need be placed in either a table or figure. Instead of a simple table, the results could 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). If the results are not significant, then it is probably not necessary to include the results in either a table or as a figure.

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Please submit tables as editable text and not as images. Tables can be placed either next to the relevant text in the article, or on separate page(s) at the end. Number tables consecutively in accordance with their appearance in the text and place any table notes below the table body. Be sparing in the use of tables and ensure that the data presented in them do not duplicate results described elsewhere in the article. Please avoid using vertical rules and shading in table cells.

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