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PROGRAMA DE PÓS-GRADUAÇÃO EM ODONTOLOGIA

INFLUÊNCIA DA PRESENÇA DE MATERIAIS METÁLICOS NA CAPACIDADE DIAGNÓSTICA DE DIFERENTES MÉTODOS POR IMAGEM – RADIOGRAFIA CONVENCIONAL, RADIOGRAFIA DIGITAL E TOMOGRAFIA COMPUTADORIZADA DE FEIXE CÔNICO – INVESTIGAÇÃO *IN VITRO*

GABRIELA SALATINO LIEDKE

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Linha de Pesquisa

Diagnóstico de Afecções Buco-Faciais

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Orientadora: Prof. Drª. HELOÍSA EMÍLIA DIAS DA SILVEIRA

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Para chegar à realidade, uma ideia começa por se apoderar de espíritos fervorosos
e escraviza-os;
A partir desse momento, eles pertencem-lhe e não vêm diante de si se não
o objetivo a atingir.
Por vezes, esse objetivo parece intangível: quanto mais nos adiantamos,
mais ele nos parece distante.
Mas que importa? Os escravos de uma ideia são incapazes de desanimar.
Marie Curie,
Física polonesa (1867 – 1934).

RESUMO

O objetivo desta tese foi avaliar a interferência da presença de materiais metálicos na imagem radiográfica e tomográfica por meio da análise da adaptação marginal de restaurações e coroas metálicas. Esta investigação resultou em 3 artigos: uma revisão sistemática da literatura para identificar o estado da arte com relação ao uso dos métodos radiográficos; um estudo *in vitro* comparando o desempenho do filme radiográfico convencional e dos sistemas digitais VistaScan Dürr Dental, Digora Classic Soredex e Express Instrumentarium – com e sem o emprego de filtros para o pós processamento da imagem; e um estudo *in vitro* avaliando o processamento das imagens da TCFC – utilizando diferentes espessuras de reconstrução. Na revisão sistemática foram incluídos 14 estudos, sendo classificados de baixa ou moderada qualidade, de acordo com os critérios QUADAS de classificação. Na investigação radiográfica (artigo 2), os maiores valores de sensibilidade (0,67 – 0,83), especificidade (0,81 – 0,92) e acurácia (0,73 – 0,86) foram obtidos com radiografias convencionais e imagens digitais originais. Na avaliação tomográfica (artigo 3), os valores da aucROC variaram de 0,60 a 0,72, sendo que o limite inferior do intervalo de confiança mostrou-se abaixo ou muito próximo da linha de referencia. Frente aos resultados, conclui-se que imagens radiográficas originais (convencionais ou digitais) devem ser preferidas para a avaliação de dentes com restaurações metálicas. Quanto à TCFC, mesmo quando se aumenta a espessura de reconstrução da imagem e diminui-se o artefato, ainda assim não há melhora na acurácia do diagnóstico.

Descritores: Diagnóstico por imagem, radiografia digital, tomografia computadorizada de feixe cônico, adaptação marginal dentária

ABSTRACT

The aim of this thesis was to evaluate the interference of the presence of metallic materials on radiographic and tomographic image by assessing misfits tooth and restoration in metal-restored teeth. This investigation resulted in three articles: a systematic review of the literature to identify the state of the art on the use of radiographic methods; an *in vitro* study comparing the performance of conventional film and digital phosphor plate systems Vistascan Dürr Dental, Digora Classic Soredex and Instrumentarium Express – exported as original images and with the use of post processing filters; and an *in vitro* study evaluating the post-processing of CBCT images – using diverse reconstruction thicknesses. The systematic review retrived 14 studies, classified as low- / moderate quality based on QUADAS criteria. For radiographic evaluation (article II), higher sensitivity (0.67 ─ 0.83), specificity (0.81 ─ 0.92) and accuracy (0.73 ─ 0.86) values were obtained with conventional and digital original images. For tomographic evaluation (article III), mean aucROC ranged from 0.60 to 0.72, and the analysis of the 95% CI showed the lower bound of the curve bellow or very close to the reference line. Based on the results, it is concluded that original images (conventional or digital) should be preferred for the assessment of teeth with metal restorations. Considering CBCT images, even thought increased reconstruction thickness decreased perceived artifact, it did not improve diagnosis accuracy.

Key-words: Diagnostic imaging, radiographic image enhancement, cone-beam computed tomography, dental marginal adaptation

LISTA DE ABREVIATURAS E SIGLAS

ANOVA – *Analysis of Variance* / Análise de Variância

CCD – *charge-coupled device* / dispositivo de carga acoplada

CI – *confidence interval* / intervalo de confiança

CMOS – *complementary metal oxide semiconductor* / semicondutores de óxido de metal complementares

FO-UFRGS – Faculdade de Odontologia - Universidade Federal do Rio Grande do Sul

FOV – *field of view* / campo de visão

kVp – kilovolt pico

mA – miliampere

mm – milímetros

Pixel – *picture elemento*

pl/mm – pares de linha por milímetro

PSP – *photostimulable phosphor plate* / placa de fósforo fotoestimulada

s – segundos

TC (CT) – tomografia computadorizada */ computed tomography*

TCFC (CBCT) – tomografia computadorizada de feixe cônico / *cone beam computed tomography*

TCMD (MDCT) – tomografia computadorizada de multi-detectores / *multidetector computed tomography*

UFRGS – Universidade Federal do Rio Grande do Sul

Voxel – *volume element*

SUMÁRIO

1 INTRODUÇÃO

A ausência de adequada adaptação marginal de próteses e restaurações dentárias é dita como um dos fatores relacionados com o desenvolvimento de doença periodontal e cáries recorrentes. Sorensen et al. (1) relatam maior perda óssea adjacente a coroas totais com desadaptação marginal maior do que 0,05 mm. Associações entre discrepância marginal e sinais clínicos de inflamação periodontal com reduzido nível clínico de inserção também são relatadas na literatura (2, 3). Cáries recorrentes são mais frequentemente encontradas na margem gengival de restaurações (4, 5), sendo que uma revisão sistemática sugere que a localização supra ou subgengival não tenha impacto na incidência da doença (6). Totiam et al. (7) e Cenci et al. (8) observaram uma correlação positiva entre a presença de falha entre o material restaurador e o tecido dentário e o desenvolvimento de lesão de cárie, porém apenas na ausência de flúor (8). Ainda, Ozbas et al. (9), avaliando a qualidade do tratamento endodôntico e presença de lesão periapical, verificaram uma relação estatisticamente significativa entre restaurações coronárias desadaptadas e lesões endodônticas.

Um artigo de revisão aponta a presença de cárie secundária como o maior motivo para substituição de restaurações, sendo que este diagnóstico constitui uma importante parcela do tratamento odontológico (4). Mesmo que nem todas as restaurações defeituosas dêem origem à lesões, idealmente deve-se observar uma continuidade entre o material restaurador e as margens do preparo dentário (2). A ausência de adaptação marginal pode ser verificada no plano vertical (presença de uma abertura na interface dente/restauração), no plano horizontal (excesso ou falta de material restaurador), ou uma combinação dos anteriores (2).

O método visual com o auxílio da sonda exploradora é descrito na literatura como clinicamente acurado (5). Entretanto, Eidelman et al. (10) observaram que a avaliação clínica não é capaz de detectar grande proporção de casos com falta de adaptação marginal; Felton et al. (2) verificaram baixa correlação entre o diagnóstico clínico da desadaptação proximal realizado com o uso de sonda exploradora e o resultado da medida da impressão observada com o microscópio eletrônico de varredura, sugerindo que o primeiro possa gerar dúvidas para o diagnóstico; e Mjor (4) questiona o método clínico para inspeção marginal, uma vez que a visão direta fica comprometida e a sonda exploradora tende a prender independente se a margem encontra-se defeituosa ou não. Assim, a utilização de radiografias para melhor avaliação das superfícies proximais restauradas parece ser um consenso indicado pela literatura (4, 11-14).

1.1 Radiografia digital

O desenvolvimento da radiologia digital trouxe algumas vantagens para o cirurgião-dentista e o paciente, como diminuição do tempo de exposição à radiação, ausência do processamento químico e dos erros advindos desta etapa, facilidade na troca de informação e possibilidade de manipulação da imagem (15-20). Dentre os estudos que compararam o diagnóstico realizado com os métodos convencional e digital, a maioria encontrou correspondência entre eles, e hoje as radiografias digitais são aceitas como equivalentes ao consagrado método convencional (21-29).

Atualmente, dois tipos de receptores digitais estão presentes no mercado: estado sólido (CCD ou CMOS) e placa de fósforo fotoestimulável. Basicamente, os sensores de estado sólido são placas rígidas com 5 a 7mm de espessura, que podem ou não apresentar um cabo com transmissão instantânea da imagem para o computador; já as placas de fósforo são sensores flexíveis e necessitam de um scanner a laser para seu processamento e visualização da imagem no computador (30). Os estudos apontam equidade entre os resultados destes sistemas digitais (18, 22, 31), embora o desconforto para o paciente e a necessidade de repetição das radiografias possam ser maiores no caso dos sensores sólidos (32, 33). Assim sendo, a placa de fósforo parece ser o meio digital de melhor adaptação para o paciente (34, 35). Wenzel e Kirkevang (18) investigaram a utilização de dois tipos de sistemas digitais por alunos de graduação e detectaram como vantagem do CCD a economia de tempo e da placa de fósforo a facilidade de posicionamento.

A resolução espacial (pares de linhas ou número de *pixels* por milímetro) e a profundidade de cor ou resolução de contraste das radiografias digitais são parâmetros utilizados para medir a qualidade da imagem. A resolução espacial influencia no detalhe observado, sendo que a maioria dos sistemas possui entre 6 e 20 pl/mm. No caso da profundidade de cor, um aumento no contraste determina maior resolução, sendo que a maioria das imagens são apresentadas com 8-bits, significando que 256 tons de cinza estão disponíveis, porém alguns sistemas trabalham com 12-bit (4.096 tons de cinza) ou 16-bit (65.536 tons de cinza). Juntamente com uma possível melhora na resolução e detalhe da imagem, o aumento nesses parâmetros requer maior espaço de armazenamento e, muitas vezes, maior dose de radiação (36, 37). Avaliando a relação entre resolução espacial e contraste, Brüllmann, et al. (38) verificaram que a resolução medida com 10% do contraste mostrou-se bem abaixo da resolução dos sensores. Entretanto, a avaliação destes parâmetros mostra resultados diversos para o diagnostico. No caso da avaliação do comprimento endodôntico, imagens com alta resolução espacial e alto contraste apresentaram-se superiores (39). Já na avaliação de lesões de cárie, pouca ou nenhuma influência foi observada (37, 40).

No processo convencional, o filme radiográfico é o responsável pela aquisição e armazenamento da imagem; já no digital, um sensor recebe a energia dos raios-x, converte o sinal analógico para digital e o transmite para o computador, onde a imagem será guardada em uma matriz numérica (41). Tal matriz é composta por células ordenadas em linhas e colunas, sendo que cada célula, ou *pixel*, armazena as coordenadas x- e y- e o valor de cinza correspondente à atenuação dos raios-x (15, 41). As radiografias convencionais, após a exposição e o processamento, não permitem que sua imagem seja alterada; por outro lado, nos sistemas digitais é possível aplicar operações matemáticas para modificar os parâmetros da imagem (valor de cada *pixel*), conforme a necessidade clínica (15, 42-44).

Qualquer operação que compreenda alteração do brilho, contraste, realce, nitidez ou suavização da imagem digital é conhecida como processamento (15). Brilho, contraste e inversão são funções lineares e reversíveis, que alteram todos os valores de pixel vistos na imagem na mesma proporção. Dessa forma, quando o brilho é alterado, os valores de todos os pixels são movidos na mesma direção, e a distância entre cada pixel permanece constante. Já no ajuste de contraste, a escala de tons de cinza é esticada (aumento do contraste) ou reduzida (diminuição do contraste). Inversão, ou contraste reverso, constitui na inversão dos valores da escala de tons de cinza (0 – 255) de cada pixel da imagem; assim, o que era escuro passa a ser vizualizado claro e vice-versa. Ao contrário do brilho, contraste e inversão, o gama é uma função não-linear e, por isso, a modificação imposta na imagem é irreversível, já que altera o brilho dos pixels com valores médios de tons de cinza. Assim, tem-se uma grande modificação dos tons de cinza intermediários, sem, no entanto, haver alteração dos valores extremos (0 e 255) (43, 45).

A otimização do brilho e contraste da imagem pode ser utilizada para corrigir possíveis erros de sub- ou sobre-exposição, evitando a realização de outra radiografia (15, 30). Ainda, tais ajustes permitem o realce de determinadas regiões da imagem, otimizando a visualização de certos limites entre as estruturas (15). Um estudo observou que a ferramenta mais utilizada por cirurgiões-dentistas durante o pós-processamento de imagens digitais foi o gama (45). Tal fato é compreensível, visto que os tons de cinza intermediários são os mais prevalentes na imagem, e por isso seu processamento torna-se relevante para o diagnóstico odontológico.

Entretanto, a alteração espontânea do brilho e contraste pode ser um procedimento arbitrário, e prejudicial para a avaliação, caso o dentista/radiologista não esteja familiarizado com o processo (15, 46). Nair e Nair (29) observaram que a experiência do examinador com o sistema digital e suas ferramentas disponíveis interferem positivamente na ocasião da interpretação. Ainda, Wenzel et al. (47) verificaram que a falta de familiaridade do examinador com o sistema digital está mais intimamente correlacionada com resultados falso-positivos do que o emprego de filtros para manipulação da imagem. A literatura sugere a utilização de processamentos pré-estabelecidos, ou a aplicação de filtros específicos para cada situação clínica, o que diminuiria o tempo de manipulação da imagem digital, reduziria os erros advindos desta etapa e aumentaria a precisão do diagnóstico (22, 46). Neste caso, uma matriz pré-estabelecida é aplicada na imagem para alterar o valor de cada pixel considerando o valor dos pixels vizinhos. Dependendo do tipo da matriz empregada, a imagem pode adquirir um aspecto suavizado (*smooth*) ou endurecido (*sharpen*), e a intensidade do resultado depende do grau de penetração utilizado. Ainda, os autores apontam que a escolha do filtro aplicado às radiografias digitais deve ser feita conforme a indicação clínica do exame (42).

Alguns estudos têm sugerido que o aumento do contraste e a aplicação de filtros específicos podem contribuir para favorecer a acurácia do exame radiográfico digital. Yalcinkaya et al. (48) compararam os diferentes filtros disponíveis no sistema Dürr Dental para a identificação das estruturas anatômicas e verificaram que sua utilização melhorou a qualidade da imagem, ainda que, sem diferença estatística quando comparada com a radiografia convencional. Wenzel e Hintze (42) conduziram um estudo para verificar a preferência do cirurgião-dentista em relação à utilização dos filtros em radiografias intrabucais; verificaram que, na maioria dos casos, a imagem tratada foi a eleita.

Quanto à detecção de cáries dentárias, Haiter-Neto et al. (49), avaliando o desempenho de sistemas rígidos tipo CCD, não observaram diferenças entre as marcas comerciais investigadas e entre a utilização ou não dos filtros disponíveis. Por outro lado, utilizando placas de fósforo, os mesmos autores verificaram que o uso de filtros intermediários apresentou melhor desempenho para o diagnóstico de lesões de cárie incipientes do que aqueles com maior penetração (49). Da mesma forma, Moystad et al. (50) e Svanæs et al. (51) observaram desempenho superior das imagens que receberam a aplicação de filtro para o diagnóstico de lesões de cárie em metade externa de esmalte.

Investigando os sistemas digitais para a determinação do comprimento endodôntico, Wenzel e Kirkevang (18) observaram que a maioria dos examinadores utilizou filtros de realce de bordas e Kal et al. (52) encontraram que os filtros inversão, contraste/brilho e realce de bordas foram os que apresentaram os melhores resultados. Já Woolhiser et al. (25) não observaram diferenças estatisticamente significativas quando compararam os filmes convencionais D-*speed* e F-*speed* com o sistema digital com e sem a utilização da ferramenta de realce *Revealier*.

Com relação ao tecido ósseo, Vandenberghe et al. (53) verificaram que a avaliação subjetiva da lâmina dura, padrão trabecular e presença de perdas ósseas verticais ou em região de furca não foi influenciada pelo tipo de sistema radiográfico utilizado (convencional ou digital); entretanto, os autores apontam a necessidade de investigar a utilização dos filtros de imagens nessas situações. *Eickholz* et al. (54) não observaram diferenças entre a imagem original não manipulada e com filtros aplicados comparadas à real medição transcirúrgica na avaliação da perda óssea interproximal. Quando lesões ósseas in vitro foram investigadas, Hadley et al. (55) verificaram superioridade dos sistemas digitais com aplicação de filtros quando comparados com a imagem sem filtro e com o filme radiográfico D-*speed*.

Quanto à adaptação marginal de restaurações, Haak et al. (23) observaram desempenho semelhante dos sistemas digitais e filmes radiográficos convencionais na investigação da adaptação marginal de restaurações com resina composta. Entretanto, os autores supracitados não comentam se foi utilizado algum filtro nas imagens digitais. Já Brettle e Carmichael (56), para a investigação do efeito dos filtros radiográficos na identificação de recorrência de cárie e desadaptação marginal em restaurações metálicas, utilizaram segmentos de radiografias panorâmicas com e sem o processamento da imagem. Neste estudo os autores verificaram que muitas das radiografias diagnosticadas como “sem alterações” tiveram seus diagnósticos modificados para “com alterações” após o processamento das imagens, provavelmente pela visualização de linhas radiolúcidas adjacentes às restaurações ou coroas metálicas. Estes artefatos na imagem radiográfica digital já haviam sido reportados por Schweitzer e Berg (57), que recomendaram cautela na interpretação, uma vez que poderiam resultar em diagnósticos falso-positivos.

A imagem radiográfica é uma projeção bidimensional de uma estrutura tridimensional, representada em uma escala que vai do preto ao branco puros, passando pelos tons de cinza. Por este motivo, está sujeita à formação de artefatos. Os artefatos são regiões da radiografia que, pela sua apresentação, podem prejudicar a imagem, simular uma condição clínica ou ofuscar alguma patologia (58, 59).

Nas radiografias convencionais, é possível observar uma banda clara ou escura no limite entre áreas com diferentes densidades, conhecida como efeito *Mach band* (bandas de Mach) (60). Estas linhas, ou faixas, não existem realmente na imagem, apenas são percebidas pelo olho humano, como uma ilusão de óptica. Alguns estudos já demonstraram como este fenômeno pode interferir no diagnóstico de algumas condições clínicas (61, 62).

As radiografias digitais necessitam dos mesmos cuidados técnicos das tomadas convencionais para evitar falhas na imagem e, consequentemente, interpretações errôneas. O adequado posicionamento do paciente, seleção dos parâmetros de exposição e o emprego da técnica apropriada e correta são requisitos básicos que devem ser observados. Adicionalmente, novos erros podem ser introduzidos, pela diferença na metodologia de aquisição e processamento da imagem digital (59, 63-65).

Como mencionado anteriormente, a principal diferença entre os métodos convencional e digital está no processamento da imagem. O processamento da radiografia digital envolve a manipulação matemática dos dados, com o objetivo de modificar o contraste das estruturas mais relevantes (63, 64). Entretanto, a intensificação das bordas, pelo aumento do contraste radiográfico, gera o aparecimento de um tipo de artefato em forma de linha radiolúcida no limite de estruturas com grande diferença de densidades, conhecido como *Uberschwinger*, ou efeito rebote (58). Esta linha radiolúcida é predominantemente observada na periferia de metais e pode atrapalhar o diagnóstico, simulando perda de composição. A literatura médica e odontológica reporta a presença destes artefatos na imagem, gerados pela utilização de filtros para realce de bordas, e determinando a simulação de lesão ou desadaptação adjacentes a materiais metálicos (57, 64, 65). Entretanto, apesar de alguns autores recomendarem cautela na avaliação de materiais metálicos, a literatura não contém estudos controlando fatores como a adaptação clínica de restaurações e próteses para investigar a capacidade diagnóstica das radiografias digitais, a interferência da utilização de filtros na imagem digital e o efeito rebote.

1.2 Tomografia computadorizada de feixe cônico

Nos últimos anos, com o desenvolvimento dos aparelhos de tomografia computadorizada de feixe cônico (TCFC), a solicitação de exames tridimensionais na Odontologia experimentou um crescimento significativo. A TCFC apresenta algumas vantagens quando comparada à tomografia computadorizada (TC) tradicional, principalmente com relação à redução da dose de radiação recebida pelo paciente (66-72).

O exame por TCFC permite ao profissional uma melhor visualização das estruturas crânio-maxilo-faciais, auxilia no plano de tratamento e possibilita o acompanhamento dos resultados ao longo do tempo. Nesse sentido, diversos estudos e relatos de casos demonstram a aplicabilidade deste exame, bem como sua equidade diagnóstica com a TC tradicional, nas diversas especialidades (73). Além de avaliações amplas do complexo maxilo-facial, a TCFC também está sendo solicitada para investigações do elemento dentário, principalmente com relação a complicações endodônticas (74-79).

É fundamental para o paciente que os benefícios de um exame radiográfico seja equilibrado com o risco de exposição à radiação ionizante. No caso de uma avaliação tomográfica, na qual a dose de radiação é muito mais elevada, especialmente quando FOVs de maiores dimensões são empregados, este postulado fica ainda mais evidente (67, 71, 72). Dessa forma, sempre que um exame de TCFC é solicitado, é importante otimizar o volume adquirido e investigá-lo em toda sua extensão, para contemplar outros diagnósticos além daquele que levou à sua solicitação (80). Esta medida visa manter a dose de radiação a qual o paciente é submetido tão baixa quanto o possivel, de acordo com o princípio ALARA (*As Low As Reasonably Achievable*), introduzido pela Comissão Internacional de Proteção à Radiação em 1990 (81). Portanto, alterações que normalmente não necessitariam de um exame tomográfico para serem diagnosticadas começaram a ser avaliadas.

Neste sentido, alguns estudos foram realizados utilizando a TCFC no que tange a pesquisa de alterações coronárias, e alguns encontraram concordância entre os métodos radiográficos convencional e/ou digital com a TCFC para o diagnóstico de lesões de cárie em esmalte (82-86). Verifica-se que a maioria dos estudos disponíveis na literatura utilizaram-se de dentes sem restaurações metálicas, fato que pode ter contribuído para a alta sensibilidade do exame tomográfico encontrada por alguns autores. Foi identificado um artigo que objetivou o diagnóstico de cáries secundárias mecanicamente criadas adjacentes à restaurações metálicas, relatando um melhor desempenho das imagens de TCFC do que com radiografias interproximais (87). No entanto, este estudo trabalhou com defeitos consideravelmente grandes (1,4 mm de diâmetro), o que pode explicar os resultados encontrados.

Apesar da TCFC ser o exame de eleição para a avaliação pré-cirúrgica a instalação de implantes osseointegrados (88), tal exame não é recomendado durante a avaliação pós-operatória deste tratamento, devido a presença de artefatos gerados na imagem pelo metal (88, 89). Vários estudos abordam o problema de lidar com materiais metálicos ao avaliar imagens tomográficas. Sanders et al. (90) observaram que a presença de braquetes ortodônticos metálicos afetou a qualidade da imagem, prejudicando a detecção de lesões cariosas interproximais. Similarmente, a acurácia do exame tomográfico para diagnosticar complicações endodônticas também foi diminuída quando o conduto radicular encontrava-se preenchido por material endodôntico e/ou pino metálico (76, 79).

A presença de materiais metálicos ocasiona a deterioração da imagem, determinando o aparecimento de linhas brilhantes em forma de estrela originadas do metal ou o escurecimento da região adjacente a ele, o que pode comprometer a precisão do diagnóstico (91). O metal altera o comportamento dos fótons de raio-X e a maneira como o detector recebe a informação. Assim, esses fótons são altamente atenuados e a leitura realizada pelo detector pode apresentar erros devido ao endurecimento do feixe de radiação (*beam-*

hardening effect), ao espalhamento da radiação (*scatter effect*) e à baixa contagem de fótons que chega ao detector (*photon starvation*). O endurecimento do feixe de radiação e o espalhamento da radiação são diferentes mecanismos que produzem o aparecimento na imagem de zonas escuras adjacentes ao metal. O endurecimento do feixe de radiação deve-se à natureza policromática da fonte de radiação; assim, os fótons com baixa energia são absorvidos pelo metal, ao passo que os de alta energia, não são atenuados. O espalhamento da radiação refere-se à deflexão do feixe de raios-x da sua rota original, mudando a direção dos fótons, que atingem outro detector e, consequentemente, determinando uma projeção errônea dos dados. A baixa contagem de fótons pelo detector determina um erro estatístico na análise, resultando em linhas brilhantes e escuras randômicas na imagem, originadas a partir do metal, uma vez que o sinal 'zero' deve ser substituído por um 'não-zero' número de fótons pelo receptor (92-94).

Alguns fatores podem determinar o aparecimento de artefatos com maior ou menor grau de interferência na imagem, como o tipo de metal presente e os fatores elétricos do aparelho (93, 95, 96). Metais com maior número atômico atenuam mais o feixe de radiação, determinando maior informação perdida pelo detector para o processo de reconstrução da imagem (97). O aumento na kVp do aparelho determina uma melhora na capacidade de penetração do feixe de radiação e, consequentemente, uma melhor definição da imagem adquirida (96, 98). Entretanto, cabe salientar que o aumento nos parâmetros de exposição do aparelho tem como consequência o aumento na dose de radiação recebida pelo paciente (71, 72). Um estudo comparando a produção de artefato na imagem tomográfica utilizando aparelhos de TCFC e de TCMD, com parâmetros de exposição semelhantes (100kV), encontrou melhor qualidade da imagem com a TCFC (97).

Na tentativa de atenuar os artefatos após a aquisição tomográfica, algumas estratégias foram desenvolvidas. Os softwares de processamento são capazes de identificar as zonas com menor penetração dos raios-x e aplicar algoritmos de correção (95, 99). O aumento da espessura da reconstrução da imagem visualizada também seria uma opção para diminuir o efeito do artefato, porém pode exacerbar o borramento e diminuir o detalhe (95).

Por fim, diante de todo o exposto, justifica-se a realização deste estudo que busca investigar o diagnóstico radiográfico das desadaptações proximais adjacentes a materiais metálicos. Além disso, frente ao desenvolvimento e crescente solicitação de exames tomográficos, é necessário pesquisar o processamento das imagens buscando viabilizar o diagnóstico contíguo a restaurações metálicas, evitando assim, a solicitação de novos exames.

2 OBJETIVOS

2.1 Geral

Analisar a interferência da presença de materiais metálicos observada na imagem por meio da investigação da adaptação marginal de restaurações metálicas fundidas e coroas metálicas, visando identificar o melhor protocolo frente a estas situações clínicas.

2.2 Específicos

i) Realizar uma revisão sistemática da literatura para identificar o estado da arte com relação ao uso dos métodos radiográficos na avaliação da desadaptação proximal de próteses e restaurações.

ii) Avaliar, *in vitro*, o desempenho do filme radiográfico convencional e dos sistemas digitais VistaScan Dürr Dental, Digora Classic Soredex e Express Instrumentarium – com e sem o emprego de filtros para o pós processamento da imagem – no diagnóstico da adaptação marginal de restaurações metálicas fundidas e coroas metálicas totais.

iii) Avaliar, *in vitro*, o processamento das imagens da TCFC – utilizando diferentes espessuras de reconstrução da imagem – no diagnóstico da adaptação marginal de restaurações metálicas fundidas e coroas metálicas totais.

ARTIGO 1

Radiographic diagnosis of dental restoration misfit: a systematic review

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Abstract

Objective: The objective of this study was to perform a systematic review on the use of radiographic methods for the diagnosis of misfit in dental prostheses and restorations.

Material and methods: The MEDLINE bibliographic database was searched from 1950 to February 2014 for reports on the radiographic diagnosis of misfits. The search strategy was limited to English-language publications using the following combined MeSH terms in the search strategy: (Dental Restoration OR Dental Prosthesis OR Crown OR Inlays OR Dental Abutments) and (Dental Leakage OR Prosthesis Fitting OR Dental Marginal Adaptation OR Surface Properties) and (Radiography, Dental OR Radiography, Dental, Digital OR Cone-Beam Computed Tomography).

Results: Twenty-eight publications were identified and read in full text, and 14 studies fulfilled criteria for inclusion. Information regarding the use of radiographic methods for the diagnosis of misfits in dental prosthesis and restorations, and in which the methodology/results comprised information regarding how the sample was collected/prepared, the method, imaging protocol, presence of a reference test, and the outcomes were evaluated. QUADAS criteria was used to rate the studies in high, moderate or low quality.

Conclusions: The evidence supporting the use of radiographic methods for the diagnosis of misfits in dental prosthesis and restorations is limited to low- / moderate quality studies. The well-established intraoral orthogonal projection is still under investigation, and considered the most appropriate method, both when evaluating the relation between dental restoration-to-tooth and abutment-to-implant. Studies using digital radiographs have not evaluated the effect of image post-processing, and tomography has not been evaluated.

Key-words: Dental restoration, Permanent; Crown; Prosthesis fitting; Dental marginal adaptation; Dental implant; Radiography

Introduction

Proper marginal fit of dental fillings and crowns is important to prevent periodontal disease and recurrent caries, no matter the location of the margins (1-5). Several authors state that the gingival margin of a filling and a crown can be evaluated by clinical (visual inspection and/or an explorer) or radiographic methods, and also that it is considered a difficult diagnostic task, especially when the restoration margin is located interproximally and subgingivally (1, 2, 6, 7). Moreover, some authors questioned the use of the explorer, since it tends to stick whether or not the tissue adjacent to the filling is carious; thus it has been proposed that lesions adjacent to restorations may be diagnosed by radiographic methods (2, 8).

In the case of rehabilitation with dental implants, most systems have two components – the implant screw and a connecting transmucosal structure, the abutment; the prosthetic crown can be attached to the abutment, or be a separate element (9). Thus, a gap can exist between the implant and the abutment, and also a gap or an overextension of the luting agent may be seen between the abutment and the crown. Some studies have suggested radiographic evaluation to confirm the correct seating and debridement of subgingival restorations, since the presence of excess of cement may cause peri-implant inflammation (10, 11). Crestal bone changes have also been associated with marginal misfit in cement-retained implant single crowns (12).

Even though not all defective restorations give rise to disease, the proper diagnosis of marginal misfits is fundamental for the maintenance of the tooth and surrounding tissues and should be part of the overall evaluation of the quality of the restoration. Considering the radiographic assessment, the radiopacity of the restorative material and the technique were shown to influence the assessment of marginal misfits (2), but no consensus has been suggested in the literature. Thus, in an attempt to search for a rationale on the use of imaging in the light of various radiographic techniques – e.g. periapical, digital radiography and computed tomography – and in order to suggest the best radiographic protocol, the objective of this study was to perform a systematic review on the use of radiographic methods for the diagnosis of misfits in dental prostheses and restorations.

Material and methods

The MEDLINE (PubMed) bibliographic database was searched from 1950 to February 2014 for reports on the radiographic diagnosis of misfits in dental prostheses and restorations. The search strategy was limited to English-language publications in MEDLINE (PubMed) using the following combined MeSH terms in the search strategy: (Dental Restoration OR Dental Prosthesis OR Crown OR Inlays OR Dental Abutments) and (Dental Leakage OR Prosthesis

Fitting OR Dental Marginal Adaptation OR Surface Properties) and (Radiography, Dental OR Radiography, Dental, Digital OR Cone-Beam Computed Tomography).

Studies in which information regarding *(1) how the sample was collected / prepared, (2)* the index test (radiographic method), *(3)* the imaging protocol, (*4*) the diagnostic task, (*5*) the presence of a reference method (gold standard or the “best available” method) for the true state of misfit, and (6) the outcomes were selected. For studies based on categorical data, accuracy parameters such as sensitivity, specificity, likelihood ratio, or ROC curves should be present (at least one of these parameters) to qualify for inclusion. For studies using quantitative data, agreement between measurements or accuracy of measurements should be present.

Each included study was rated as high, moderate or low quality mainly based on QUADAS criteria (13), and the assessed items are presented in Table 1. All articles were screened by two reviewers, and data extraction was verified separately by all authors.

Results

Review search results

The search strategy yielded 446 publications. The initial screening of the articles was conducted using the abstracts and key words, but when these were unclear or unavailable, the full text was used.

Screening yielded 28 citations that potentially met the inclusion criteria, but 14 papers were excluded, since four did not have a reference method (14-17), five had radiographic and clinical assessments interpreted together (18-22), three evaluated the bond agent and/or composite technique appearance (23-25), and two did not perform any test to assess the outcomes (26, 27).

In this way, 14 publications were identified that tested at least one or compared two or more radiographic methods for the diagnosis of misfits in dental prostheses and restorations, and in which the methodology and result variables agreed with the inclusion criteria. Twelve studies were *in vitro*, six dealing with the marginal fit of abutments or crowns attached to implants (28-33), and six based on extracted teeth (34-39), and two were *in vivo* studies (40, 41).

The diagnostic tasks assessed were the detection of marginal gaps and/or overhangs adjacent to dental crowns and fillings, and to abutments on implants. The index test (radiographic analysis) was interpreted alone in all but one study, in which it was also considered together with clinical examination (38). Two studies also compared the results from clinical and radiographic examination against the reference method (gold standard). The reference method for *in vitro* studies was mainly based on the known condition (laboratory-made gap); two studies used a scanning electron microscope (30, 39), and one a stereomicroscope (38). *In vivo* studies had direct assessment (the best available method) as the reference method (40, 41).

The number of examiners per study ranged from one to 36, with varying degrees of experience on evaluating radiographs, but only three studies reported examiner agreement as kappa index: intra-examiner kappa ranged from 0.66 – 0.92 (31, 39), and inter-examiner kappa ranged from 0.41 – 0.79 (30, 31, 39). A categorical scale, dichotomous or ordinal, was used to evaluate the samples. Accuracy parameters such as sensitivity, specificity, likelihood ratio, or ROC curves were calculated in four studies (30, 34, 36, 39). Outcomes were also evaluated using ANOVA (32, 35), qui-square (29) or linear regression analyses (31) or by reporting the percentage of correctly identified defects/gaps.

The diagnostic accuracy (area under the ROC curve - aucROC) for radiographic examination in evaluating composite proximal margin fit was reported by two studies and ranged from 0.60 to 0.97 (34, 36). In the case of metal restorations, only one study reported accuracy parameters in evaluating amalgam restorations (aucROC 0.93) (36) and another in implant components (aucROC 0.63-0.64) (30). When the results from clinical and radiographic examination were compared, one study, assessing marginal gaps adjacent to implant components, found higher accuracy for the radiographic recording (30); in the case of Class II restorations evaluation, clinical and radiograph evaluation performed together reduced the number of false positive diagnosis (38). One *in vivo* study reported no differences between the number of correct cases diagnosed by the two methods (40) while one study found more correct cases diagnosed by radiographs (41).

The impact of the x-ray beam angulation was evaluated in five studies (28, 29, 31, 33, 37), where the authors agreed that the orthogonal projection was the most accurate angulation for marginal misfit diagnosis in dental restorations. Regarding image acquisition system, the majority of the studies used conventional film radiography, four used digital radiography, both CCD-based (charge-coupled device) sensors and PSP (photostimulable storage phosphor) systems (29, 31, 32, 34), and none assessed the use of computed tomography for misfit detection. Two papers reported equivalent results between CCD-based sensors and conventional radiographs (31, 34), and one of them found that a PSP system was inferior to both a sensor and conventional film (34). One paper dealt with digital image post-processing, suggesting the use of high-resolution images for marginal overhang detection adjacent to implant restorations (32). The impact of the exposure time on the final image was also assessed by one study, and the results showed no differences (30).

Based on QUADAS criteria analysis, none of the studies were categorized as high quality, six were of moderate quality (30, 31, 34, 39-41), and eight were considered as low quality (28, 29, 32, 33, 35-38). The main reasons that led one article to be classified as low quality were the lack of examiner agreement and/or any diagnostic accuracy parameters.

Information regarding the radiographic protocol of the studies is shown in Table 2. A compact overview of the results and the quality assessment of the studies is shown in Table 3.

Discussion

The intention with this review was to seek for a rationale on the use of radiography as an adjunct examination for diagnosing misfits in dental prostheses and restorations. After a filling or a crown is placed, it is important that the restoration surface be aligned with the tooth margin (8, 42). The lack of adaptation between the restoration and the prepared tooth is usually called a misfit and may predispose accumulation of biofilm and consequently development of a caries lesion (1, 2, 8), as well as it may be harmful to the gingival and marginal bone tissues (4, 5). Since the proper fitting of abutments on implants is important to the maintenance of periodontal health (11, 12), such studies were also included. However, the complications that may be related to the presence of misfit were not investigated. Therefore, studies in which the main objective was to investigate secondary caries were not included since the causes of secondary caries go beyond the isolated presence of a defective restoration (2, 8). Hence, the studies selected evaluated the type and size of misfit and the imaging protocol.

A clinical examination alone cannot detect all proximal defects (24), but it may be impossible to confirm a defect or gap by other methods. Thus direct assessment was considered the “best available” reference method for the *in vivo* studies included. Two studies matching this condition were selected; one reported no differences between the number of cases detected by clinical and radiographic methods (40), and the other found more cases detected by radiography, suggesting that bite-wing projections should be used in examining proximal areas (41).

The use of radiography to better assessment of restored proximal surfaces has been suggested by several authors (2, 6-8). The literature search retrieved two articles comparing clinical and radiographic examination against the reference method (laboratory-made gap as the gold standard). One article, evaluating proximal margins of Class II amalgam restorations compared radiographic examination alone to clinical and radiographic examination together, indicating that this improved the diagnostic quality (38). The results from the former study could be expected, since it combines two sources of diagnosis. However, sometimes it is not possible to have access to both methods simultaneously, e.g. in epidemiological studies, and thus it would be interesting to know the accuracy of each method *per se*, as well as the differences between them. Another study, assessing marginal gaps adjacent to implant components showed higher accuracy and higher intra-examiner reproducibility for radiographic than for clinical examination (30); the authors suggested that a radiographic control should be performed to verify the abutment seating, and that clinical examination with explorer can be used as a supplementary tool. It seems thus that studies on the validity of radiography in comparison with clinical examination are missing for assessment of misfits.

Marginal gaps appear as radiolucent areas beneath restorations, while overextension is a prolongation of the restoration. Tveit and Espelid (36) observed that marginal defects in connection with composite material were more correctly detected than those adjacent to amalgam. Haak et al (34) compared the detection of marginal gaps and overhangs on composite Class II fillings, and found that overhangs were more accurately diagnosed than gaps. In contrast, Opdam et al (39) obtained a higher sensitivity in detecting underfilled composite restorations. How the misfit will appear radiographically is dependent on the material’s radiopacity. Therefore, compounds, if not radiopaque, do not allow proper visualization using radiolographic techniques. In the case of metal restorations, the intersection of two structures of different radiopacity may predispose the viewing of a radiolucent line, known as the Mach band effect (43).

A secondary aim of this review was to suggest the best imaging protocol for radiographic evaluation of restored surfaces. Independently of the type of misfit being analyzed, it is important that the radiographic technique provides a correct projection of the structures. Some studies (28, 29, 31, 33, 37) evaluated the impact of different x-ray beam angulations on the detection of a misfit. All agreed that the orthogonal projection (perpendicular to the tooth/implant and to the receptor) was the most accurate angulation for defect detection. Some of the studies reported that depending on the gap size even a non-orthogonal projection could allow a correct diagnosis: gaps of 0.15 mm could be seen if the angle was no more deviating from the orthogonal than 15 degrees, but the authors claimed that in this case the radiographic analysis of the interface was uncertain with tube angulations of more than 5 degrees (28). On the other hand, angulations of the tube head greater than 15 degrees did not allow a proper evaluation, independent of the gap size (28, 29, 31, 33). Moreover, the studies that did not test the impact of varying angulation, adopted an orthogonal projection when acquiring the images.

The majority of the studies were performed using conventional film, and four used digital radiographs (29, 31, 32, 34). Regarding the detection of misfits, two studies reported equality between CCD-based sensors and film (31, 34), and one found that a PSP system was inferior to a CCD-sensor and film (34). However, in those former studies the use of post-processing in the digital images was not commented on. Unlike conventional film radiography, which does not allow post-processing of the image, digital systems permit modifications of pixel values, according to the clinical need (44). Nevertheless, in spite of the development in imaging techniques in the past decades, no attempt has been made for the use of post-processing in digital imaging or computed tomographic reconstructions on the assessment of misfit adjacent to dental restorations or prostheses. Only one study evaluated the impact of image resolution on the assessment of overhang adjacent to implant abutments, observing that high-resolution images allowed a more correct visualization of thin cement excess (32).

Conclusion

The evidence supporting the use of radiographic methods for the detection of misfits in dental prostheses and restorations is still limited to low / moderate quality studies, and the number of studies comparing the results from clinical and radiographic examination of marginal misfit detection is small. The optimal radiographic angulation is still under investigation though the well-established orthogonal projection is considered the most appropriate, both when evaluating the relation between dental restoration-to-tooth and abutment-to-implant. Conventional radiography is the most employed system for image acquisition, and studies using digital radiographs have not evaluated the influence of image post-processing for proximal assessment. Moreover, no studies exist on the use of tomography in this evaluation.

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References

1. Larson TD. The clinical significance of marginal fit. Northwest Dent. 2012;91:22-29.
2. Mjor IA. Clinical diagnosis of recurrent caries. J Am Dent Assoc. 2005;136:1426-1433.
3. Papageorgiou SN, Papadelli AP, Koidis PT, Petridis HP. The effect of prosthetic margin location on caries susceptibility. A systematic review and meta-analysis. Br Dent J. 2013;214:617-624.
4. Sorensen SE, Larsen IB, Jorgensen KD. Gingival and alveolar bone reaction to marginal fit of subgingival crown margins. Scand J Dent Res. 1986;94:109-114.
5. Felton DA, Kanoy BE, Bayne SC, Wirthman GP. Effect of in vivo crown margin discrepancies on periodontal health. J Prosthet Dent. 1991;65:357-364.
6. Spedding RH. Two principles for improving the adaptation of stainless steel crowns to primary molars. Dent Clin North Am. 1984;28:157-175.
7. Smith GP. The marginal fit of the full cast shoulderless crown. J Prosthet Dent. 1957;7:231-243.
8. Kidd EA. Caries diagnosis within restored teeth. Adv Dent Res. 1990;4:10-13.

9. Schwarz MS. Mechanical complications of dental implants. Clin Oral Implants Res. 2000;11 Suppl 1:156-158.

10. Pette GA, Ganeles J, Norkin FJ. Radiographic appearance of commonly used cements in implant dentistry. Int J Periodontics Restorative Dent. 2013;33:61-68.

11. Wadhwani C, Rapoport D, La Rosa S, Hess T, Kretschmar S. Radiographic detection and characteristic patterns of residual excess cement associated with cement-retained implant restorations: a clinical report. J Prosthet Dent. 2012;107:151-157.

12. Chen CJ, Papaspyridakos P, Guze K, Singh M, Weber HP, Gallucci GO. Effect of misfit of cement-retained implant single crowns on crestal bone changes. Int J Prosthodont. 2013;26:135-137.

13. Whiting P, Rutjes AW, Reitsma JB, Bossuyt PM, Kleijnen J. The development of QUADAS: a tool for the quality assessment of studies of diagnostic accuracy included in systematic reviews. BMC Med Res Methodol. 2003;3:25.

14. Assif D, Antopolski B, Helft M, Kaffe I. Comparison of methods of clinical evaluation of the marginal fit of complete cast gold crowns. J Prosthet Dent. 1985;54:20-24.

15. Kuonen P, Huynh-Ba G, Krummen VS, Stossel EM, Rothlisberger B, Salvi GE *et al.* Restoration margins in young adolescents: a clinical and radiographic study of Swiss Army recruits. Oral Health Prev Dent. 2009;7:377-382.

16. Levin L, Coval M, Geiger SB. Cross-sectional radiographic survey of amalgam and resin-based composite posterior restorations. Quintessence Int. 2007;38:511-514.

17. Kreulen CM, van Amerongen WE, Akerboom HB, Borgmeijer PJ, Gruythuysen RJ. Radiographic assessments of Class II resin composite restorations in a clinical study: baseline results. ASDC J Dent Child. 1992;59:97-107.

18. Olmez A, Cula S, Ulusu T. Clinical evaluation and marginal leakage of Amalgambond Plus: three-year results. Quintessence Int. 1997;28:651-656.

19. Fuks AB, Araujo FB, Osorio LB, Hadani PE, Pinto AS. Clinical and radiographic assessment of Class II esthetic restorations in primary molars. Pediatr Dent. 2000;22:479-485.

20. Kavvadia K, Kakaboura A, Vanderas AP, Papagiannoulis L. Clinical evaluation of a compomer and an amalgam primary teeth class II restorations: a 2-year comparative study. Pediatr Dent. 2004;26:245-250.

21. Sonbul H, Birkhed D. Risk profile and quality of dental restorations: a cross-sectional study. Acta Odontol Scand. 2010;68:122-128.

22. Tveit AB, Espelid I. Class II amalgams: interobserver variations in replacement decisions and diagnosis of caries and crevices. Int Dent J. 1992;42:12-18.

23. Pamir T, Kaya AD, Baksi BG, Sen BH, Boyacioglu H. The influence of bonding agents on the decision to replace composite restorations. Oper Dent. 2010;35:572-578.

24. Eidelman E, Fuks A, Chosack A. A clinical, radiographic, and SEM evaluation of Class 2 composite restorations in primary teeth. Oper Dent. 1989;14:58-63.

25. Holan G, Levin M, Bimstein E, Grajower R, Eidelman E. Clinical, radiographic, SEM evaluation and assessment of microleakage of Class II composite restorations. Am J Dent. 1989;2:274-278.

26. Sewerin IP. Radiographic control of fixture-abutment connection in Branemark implant technique. Scand J Dent Res. 1989;97:559-564.

27. Sailer BF, Geibel MA. Comparative analysis of intraoral radiographs with variation of tube angulation to detect insufficient crown margins. Int J Comput Dent. 2013;16:201-207.

28. Begoña Ormaechea M, Millstein P, Hirayama H. Tube angulation effect on radiographic analysis of the implant-abutment interface. Int J Oral Maxillofac Implants. 1999;14:77-85.

29. Cameron SM, Joyce A, Brousseau JS, Parker MH. Radiographic verification of implant abutment seating. J Prosthet Dent. 1998;79:298-303.

30. Konermann AC, Zoellner A, Chang BM, Wright RF. In vitro study of the correlation between the simulated clinical and radiographic examination of microgaps at the implant-abutment interface. Quintessence Int. 2010;41:681-687.

31. Sharkey S, Kelly A, Houston F, O'Sullivan M, Quinn F, O'Connell B. A radiographic analysis of implant component misfit. Int J Oral Maxillofac Implants. 2011;26:807-815.

32. Antonijevic D, Obradovic-Djuricic K, Rakocevic Z, Medigovic I. In vitro radiographic detection of cement overhangs on cement-retained implant restorations. Int J Oral Maxillofac Implants. 2013;28:1068-1075.

33. Papavassiliou H, Kourtis S, Katerelou J, Chronopoulos V. Radiographical evaluation of the gap at the implant-abutment interface. J Esthet Restor Dent. 2010;22:235-250.

34. Haak R, Wicht MJ, Hellmich M, Noack MJ. Detection of marginal defects of composite restorations with conventional and digital radiographs. Eur J Oral Sci. 2002;110:282-286.

35. O'Rourke B, Walls AW, Wassell RW. Radiographic detection of overhangs formed by resin composite luting agents. J Dent. 1995;23:353-357.

36. Tveit AB, Espelid I. Radiographic diagnosis of caries and marginal defects in connection with radiopaque composite fillings. Dent Mater. 1986;2:159-162.

37. Weyns W, De Boever J. Radiographic assessment of the marginal fit of cast restorations. J Prosthet Dent. 1984;51:485-489.

38. Espelid I, Tveit AB. Diagnosis of secondary caries and crevices adjacent to amalgam. Int Dent J. 1991;41:359-364.

39. Opdam NJ, Roeters FJ, Feilzer AJ, Smale I. A radiographic and scanning electron microscopic study of approximal margins of Class II resin composite restorations placed in vivo. J Dent. 1998;26:319-327.

40. van Amerongen WE, Eggink CO. The cervical margin of amalgam restorations: a radiographic and clinical assessment. ASDC J Dent Child. 1986;53:177-183.

41. Kroeze J, Ruiken R, van 't Hof M. Evaluation of an indirect method for assessing the quality of amalgam restorations in epidemiological studies. Community Dent Oral Epidemiol. 1988;16:208-211.

42. Holmes JR, Bayne SC, Holland GA, Sulik WD. Considerations in measurement of marginal fit. J Prosthet Dent. 1989;62:405-408.

43. Nielsen CJ. Effect of scenario and experience on interpretation of mach bands. J Endod. 2001;27:687-691.

44. Wenzel A. A review of dentists' use of digital radiography and caries diagnosis with digital systems. Dentomaxillofac Radiol. 2006;35:307-314.

Table 1 Assessment of study quality according to QUADAS

High quality	• *In vivo* studies • Adequately described and selected sample of patients who will receive the test in practice (QUADAS items 1, 2) • Presence of gold standard or the "best available" method to classify the condition (items 3, 4, 5, 6) • The index test is not part of the reference method (item 7) • The study should be described in sufficient detail to permit replication (items 8, 9) • Evaluators should be blinded to results of index test and gold standard (items 10, 11) • The index test should be interpreted alone • Report of intra- and inter-examiner reproducibility • Diagnostic accuracy presented as sensitivity, specificity, likelihood ratio, or ROC curves
Moderate quality	• *In vitro* studies meeting above criteria • *In vivo* studies which did not meet high quality criteria
Low quality	• In vitro studies which did not meet moderate quality criteria

Table 2 Summary of the diagnostic tasks, sample definition, and acquisition protocol of the radiographic examination in the included studies

Study	Diagnostic task	Sample (N/nRx)	Index test	Variations performed on acquisition	Reference test	Assessment methods
Dental restorations and prostheses						
Espelid and Tveit (38)	Evaluate proximal margins of Class II amalgam restorations	Teeth with 77 filled approximal surfaces (60/1)	Intraoral radiograph; D-speed film (Kodak)	Np	Stereomicroscope scanning	15 examiners (Nd) assessed the teeth with a sharp probe and scored the radiographic images (Nd)
Haak et al (34)	Detect marginal gap and overhang of composite resin fillings	Gaps (depth 1, 2, 3 mm; height 0.1, 0.2, 0.3 mm) and overhangs (depth 1, 1.5, 2 mm; thickness: 0.3, 0.6, 0.9 mm) on Class II cavities restored with composite (72/3)	Intraoral radiograph; F-speed film (Kodak), CCD (Dexis), PSP (Digora)	Np	Laboratory-made gap	10 examiners (university dentists) scored the images on a 5-point scale
Kroeze et al (41)	Evaluate proximal margins of amalgam restorations	MO, DO or MOD restorations from patients (290/1)	Intraoral radiograph; Nd	Np	Direct assessment**	2 examiners (Nd) scored the images on a dichotomous scale
O’Rourke et al (35)	Detect overhang of resin luting agents	Overhangs of 0, 0.5, 1, 1.5 and 2 mm of five luting agents on MOD inlay cavities (12/5)	Intraoral radiograph; D-speed film (Kodak)	Np	Laboratory-made gap	3 examiners (‘experienced’) were asked to choose the image in which they could first detect an overhang

Opdam et al (39)	Evaluate proximal margins of Class II resin composite fillings	144 Class II cavities in 72 teeth restored with different composite materials (72/72)	Intraoral radiograph; D-speed film	Np	Scanning electron microscopy	3 examiners ('experienced') scored the images on a 5-point scale
Tveit and Espelid (36)	Detect caries lesions and marginal gap of fillings	Gaps of 0, 0.5 mm and approximal caries lesions on Class II cavities restored with radiopaque composite and amalgam (65/2)	Intraoral radiograph; Film (Kodak R)	Np	Laboratory-made gap	10 examiners (dentists) scored the images on a five-point scale
van Amerogen and Eggink (40)	Evaluate proximal margins of Class II amalgam restorations	MO, DO or MOD restorations in patients (400/1)	Intraoral radiograph; Nd	Np	Direct assessment **	Nd examiners
Weyns and De Boever (37)	Detect marginal gap of crowns	Gaps of 0, 0.01, 0.05, and 0.1 mm on MOD onlay indirect cast restorations (1/100)	Intraoral radiograph; D-speed film (Kodak)	5 angulations in VP and HP (-20, -10, 0, +10, and +20 degrees)	Laboratory-made gap	14 examiners (7 dentists and 7 graduate students) scored the images on a dichotomous scale
Dental implants						
Antonijevic et al (32)	Detect cement overhang on cement-retained implant restorations	Overhangs (thickness: 0.1 - 0.5 mm, height: 0.5 and 1 mm, depth: 0.5 - 3 mm) made from 4 luting agents and Al alloy attached to metal-ceramic crowns (3/264)	Intraoral radiograph; F-speed film (Kodak), and CCD (RVG)	Digital radiographs in low and high resolution	Laboratory-made gap	5 examiners (Nd) identified the image in which they could first detect the cement excess

Begoña Ormaechea et al (28)	Detect marginal gap of abutments	Gaps of 0, 0.021, 0.042, 0.050, 0.1 and 0.15 mm on implant and abutment (1/24)	Intraoral radiograph; E-speed film (Kodak)	Four angulations in VP (0, 5, 10 and 15 degrees)	Laboratory-made gap	8 examiners (4 prosthodontists and 4 postgraduate prosthodontic students) scored the images “with” or “without” gap
Cameron et al (29)	Detect marginal gap of abutments	Gaps of 0 and 0.7 mm on external hex implants and abutments (1/40)	Intraoral radiograph; CCD (RVG)	Ten angulations of the film, or the beam in VP (0, 5, 10, 15, 20, 25, 30, 35, 40, 45 degrees)	Laboratory-made gap	36 examiners (clinicians) assessed if the radiographs were ‘good’ for the diagnostic task and scored the images “with” or “without” gap
Konermann et al (30)	Detect marginal gap of abutments	Gaps between 0 and 0.286 mm on internal hex implants and abutments (5/6)	Intraoral radiograph; Film (AGFA)	Two exposure times (0.1 s, 0.2 s)	Scanning electron microscope	15 examiners (5 dental students, 5 clinicians, and 5 postdoctoral prosthodontic residents) performed clinical examination with explorer and scored the images on a 5-point scale
Papavassiliou et al (33)	Detect marginal gap of abutments	Gaps of 0, 0.2, and 0.5 mm on internal and external hex implants and abutments (2/39)	Intraoral radiograph; F-speed film (Kodak)	13 angulations in VP (+30, +25, +20, +15, +10, +5, 0, -5, -10, -15, -20, -25, -30 degrees)	Laboratory-made gap	1 examiner (clinician) scored the images “with” or “without” gap, measuring its thickness when viewing the

						projection with and without magnification with a slide projector
Sharkey et al (31)	Detect marginal gap of abutments	Gaps of 0, 0.0127, 0.025, 0.038, 0.051, 0.063, 0.076, 0.088, 0.102, 0.114, 0.127, and 0.190 mm on internal and external hex implants and abutments (24/16)	Intraoral radiograph; F-speed film (Kodak), and CCD (Dexi)	Eight angulations in VP (0, 5, 10, 15, 20, 25, 30, 35 degrees)	Laboratory-made gap	3 examiners (with 10 years' experience in implant dentistry) scored the images "with" or "without" gap

N = number of teeth/implants used; nRx = number of radiographic projections per tooth/implant analyzed; MO = mesio-oclusal; DO = disto-occlusal-; MOD = mesio-occluso-distal; CCD = charge-coupled device; PSP = photostimulable storage phosphor; VP = vertical plane; HP = horizontal plane; Np = not performed; Nd = not defined

Table 3 Summary of the results of the included studies

Study	Reproducibility	Accuracy parameters	x-ray beam angulation	Main results	Study quality *
Dental restorations and prosthesis					
Espelid and Tveit (38)				Clinical examination combined with the radiographic reduced false positive diagnosis for secondary caries and marginal defects and increased true positive diagnosis, compared to radiographic assessment alone	Low
Haak et al (34)		Gap: aucROC CR = 0.64 aucROC CCD = 0.66 aucROC PSP = 0.60 Overhang: aucROC CR = 0.91 aucROC CCD = 0.91 aucROC PSP = 0.92		Higher aucROC obtained with conventional and CCDsystems than PSP for gap detection. More correct diagnosis when assessing overhang than gap	Moderate
Kroeze et al (41)				Overextended margins and approximal margin caries were diagnosed in a higher number with radiography than clinically	Moderate
O'Rourke et al (35)				The threshold for detection of marginal overhangs increased with the increase of the luting agent radiopacity. Even the most radiopaque materials could not be detected in association with radiopaque resin composite inlays	Low

Opdam et al (39)	Inter-examiner = 0.66 – 0.82 Intra-examiner = 0.60 – 0.68	Underfilled: sensitivity = 0.54 specificity = 0.87 Overfilled: sensitivity = 0.04 specificity = 0.96			Moderate
Tveit and Espelid (36)		Marginal defects: aucROC C = 0.97 aucROC Am = 0.93 Secondary caries: aucROC C = 0.87 aucROC Am = 0.78			Low
van Amerogen and Eggink (40)				No differences between the number of cases diagnosed by direct assessment or radiographs	Moderate
Weyns and De Boever (37)			The orthogonal projection resulted in more correct diagnosis. Only a very slight divergence of the beam in the vertical plane (+10 degrees) was acceptable		Low
Dental implants					
Antonijevic et al (32)				The threshold for detection of marginal overhangs was lower for DR with high resolution than DR with low resolution or CR	Low

Begoña Ormaechea et al (28)			The orthogonal projection allowed more accurate results. A 5-degree angle of the x-ray beam did not significantly affect the detection of gaps ≤ 0.05 mm		Low
Cameron et al (29)			The beam angulation was more important than the film placement. An angulation of the beam between perpendicular and < 20 degrees to the long axis of the implant resulted in an image proper for diagnosis		Low
Konermann et al (30)	Inter-examiner radiography = 0.41 – 0.60 Inter-examiner clinic = 0.00	aucROC radiography = 0.63 – 0.64 aucROC clinic = 0.52 – 0.60		No differences between exposure times or groups of examiners	Moderate
Papavassiliou et al (33)			The orthogonal projection allowed more accurate results. No gap		Low

			could be diagnosed with angulations > 20 degrees		
Sharkey et al (31)	Intra-examiner = 0.77 – 0.92 Inter-examiner = 0.75 – 0.79		The orthogonal projection allowed more accurate results. Even large gaps could not be detected with angle > 15 degrees.	DR allowed more accurate results for small gaps. No differences between the types of implant (int/ext hex).	Moderate

* Study quality based on QUADAS criteria described in Table1; ** Direct assessment consisted of visual examination with mouth mirror and probe;
Nd = not defined; aucROC = area under the ROC curve; CR = conventional film radiograph; DR = digital radiograph; CCD = charge-coupled device; PSP = photostimulable storage phosphor; Am = amalgam; C = composite

ARTIGO 2

Assessment of misfit between tooth and restoration in metal-restored teeth using conventional and digital radiography

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Abstract

Statement of problem. The post-processing of digital images with enhancement filters could lead to the presence of digital artifacts and result in false-positive diagnoses.

Purpose. To analyze the performance of conventional and digital radiographic images with and without filters when assessing a misfit between tooth and restoration in metal-restored teeth.

Materials and Methods. Forty teeth with MOD inlays and 40 with crowns (each with 40 perfect fit, 20 0.2 mm gap, and 20 0.4 mm gap) were imaged with conventional film and digital phosphor plate systems. Digital radiographs were exported as original images and with edge enhancement (high and low), inversion and pseudo-3D filters. Four examiners assessed the presence of gaps using a categorical scale (fit, misfit, cannot decide). Sensitivity, specificity and overall accuracy were calculated for each variable. A multivariate logistic regression was performed with accuracy as the dependent variable. Also, time spent scoring the images was assessed.

Results. 6.2% of the images received the score ‘cannot decide’; the majority with a high edge enhancement filter in the Crown group. Higher sensitivity (0.67 ─ 0.83), specificity (0.81 ─ 0.92) and accuracy (0.73 ─ 0.86) values were obtained in conventional and digital original images. Logistic regression showed restoration type, gap size, and high enhancement and inversion filters with statistically significant impact on accuracy ($p < 0.05$). Examiners spent least time scoring digital original images.

Conclusion. Original images should be preferred for the assessment of teeth with metal restorations. High enhancement filters and image inversion should be avoided, especially when metal crowns are present.

Clinical Implications. The radiographic analysis of metal restored teeth with digital systems is influenced by the use of the different filters available in the software. Particularly, high enhancement and inversion filters should be avoided.

INTRODUCTION

Radiographic examination may aid in identifying a misfit between the dental hard tissues and margins of fillings or crowns in proximal surfaces. A misfit may lead to the presence of secondary caries, crestal bone level loss, and periapical lesions no matter the location of the crown margin.[1-4] The development of digital radiology has brought some advantages for the dentist and the patient, among others the possibility of image enhancement,[5,6] and a wide variety of algorithms can be applied to the image, making relevant structures for the diagnosis more prominent.[7-9]

Some studies suggested that the use of enhancement filters would be beneficial to the diagnostic task of detecting caries lesions,[10,11] bone lesions,[12] measuring peri-implant bone level,[13] and for file length measurements.[14] However, depending on the structure being radiographed and the filter used, noise may be introduced in the image, impairing the correct diagnosis, especially when metal components are present.[15-17] Brettle and Carmichael[15] suggested that an increase in false-positive diagnoses may occur after processing the images with enhancement filters, once they observed that many radiographs diagnosed as "no pathology" changed diagnosis to “pathology”, and attributed this to the viewing of a radiolucent line adjacent to the metal restorations. In conventional radiographs, this radiographic effect may be seen at the intersection of two structures of different radiopacity and is known as the Mach band effect.[18] For the same reason, Schweitzer and Berg[19] recommended caution in the interpretation of filtered radiographs, since it could lead to the presence of digital artifacts and result in false-positive diagnoses. However, these two former studies were based solely on radiographic findings, and did not have a gold standard for validation of the results.

Thus, the aim of this study was to analyze the performance of conventional and digital radiographic images with and without filters when assessing a misfit between tooth and restoration in metal-restored teeth. Further, time consumption when assessing the images was investigated. The null hypotheses were that no significant difference would be found in the comparison between conventional and digital original images, nor among the different post-processing filters.

MATERIALS AND METHODS

Preparation of teeth and restorations

This project was approved by the Ethics Committee in Research from the Institution (n. 225.034). Eighty extracted sound human premolars teeth were used for the study. Forty premolars (test teeth) were randomly selected and prepared to receive a mesio-occluso-distal inlay (MOD group), and 40 premolars (test teeth) to receive a full crown (Crown group). A 1.4 mm diameter tapered flat end burr (KG; Sorensen) was used to prepare the teeth. The gingival floor of the inlays was located 1.5 mm coronal to the cemento-enamel junction, and the crown margins were located at the cemento-enamel junction. Two metal alloy (V-Fit Cast Ni-Cr; Talmax) restorations were made for each tooth in both the MOD and crown group. Thus, each tooth was waxed up twice: the first time with the restoration perfectly adapted to the preparation margins, and on the second time with a gap of either 0.2 mm or 0.4 mm (20 teeth with each gap size). Then, the wax was vacuum-invested and the inlay or crown was cast. The proximal extent of the gap was checked with a digital caliper (Cen-Tech; CE) under 10x magnification (MU-M19; D.F. Vasconcellos). The restorations were not cemented, but smoothly placed in position. Besides those 80 test teeth, another six pre-molars and 6 molars were selected to secure approximal contact.

Radiography of teeth with restorations

Each test tooth and one of the six pairs of non-test teeth were placed in plastic blocks with a type III stone plaster (Herodent; Vigodent) and sawdust mixture to simulate alveolar bone and to allow that the position be kept during all radiographic examinations. The tooth blocks were positioned on a flat, stable surface before radiographic examination. The paralleling technique was used with 40 cm focus-tooth distance and 2 cm tooth-receptor distance; the vertical angle was perpendicular to the buccal surface of the specimen, and the receptor and the horizontal angulation parallel to the proximal surfaces of the teeth.

Each block was imaged with four radiographic systems: the conventional radiographic film Kodak Insight No. 2 and storage phosphor plate systems of trademarks VistaScan, Digora Classic and Express. Prior to the acquisition of all images, one block was radiographed with the digital and conventional systems using exposure times of 0.2, 0.3, 0.4, 0.5 and 0.6 s. Two observers in consensus determined which image had the best diagnostic quality of the test tooth for each dental unit and system tested, and then the exposure time selected was used throughout the study. Table 1 presents the parameters of each system used in the experiment.

Conventional radiographs were developed in an automatic processor (DENT-X 9000; Elmsford) and stored on cards, coded for the categories of fit/misfit. The digital processing of phosphor plates took place in the manufacturer's system scanner, as follows: VistaScan Mini (Dürr Dental), Digora Classic (Digora Soredex Orion Corporation) and Express (Instrumentarium). Since the same tooth was imaged twice with each system (with a restoration without misfit and one with – 0.2 or 0.4 mm – misfit), 50% of the sample in each restoration group had a misfit and 50% had no misfit. Figure 1 shows digital original images of teeth in the Crown group and in the MOD group with fit and misfit restorations.

Considering the high number of filters available in the software DBSWin (Dürr Dental AG), Digora for Windows (Soredex Orion Corporation) and CliniView (Instrumentarium Dental), two radiologists in consensus evaluated all of them in a pilot study comprising five radiographs of each group and determined the most suitable for the evaluation of the entire sample. Three types of predefined filters, common for all software systems, were selected: edge enhancement, inversion and pseudo 3D. The edge enhancement filter was available in different degrees and two (low and high) were implemented. After post-processing, the images were exported and saved in TIF format. Therefore, five digital images per system were available for each restoration category: one original and four filtered (Table 1). Examples of digital radiographs after the appliance of the filters in a tooth with a fit crown and a tooth with a fit MOD inlay are shown in Figure 2.

Conventional radiographs were evaluated on a light box with black masking in an environment with controlled lighting, and the observers were allowed to use a 1.5x magnifying viewer. The digital images were assessed on a 22-inch flat screen monitor

(L2250pwD; Lenovo, and AOC) in a room with subdued light. Dedicated software (UniscoreL, designed by senior programmer Erik Gotfredsen, School of Dentistry, University of Aarhus, Denmark) was used to display the images in full size, 1:1 on the monitor, in a blinded and random sequence. The use of traditional image ajustment tools (zoom, gamma curve, brightness and contrast) was allowed. The software kept track of how many seconds the examiners spent assessing each image and how these tools were used.

Four examiners (two third-year PhD students in oral radiology – Ex1 and Ex2, one PhD in oral radiology – Ex3, and one first-year PhD student in oral radiology – Ex4, all dentists) performed the analysis of the images. Before the study, the examiners received a presentation lecture to become familiar with the filters and the scoring program. The assessment of the images for the presence of marginal gaps was based on a three-point scale (score '0' = No, there is no misfit, score '1' = Yes, there is a misfit, and score '9' = I cannot decide). The examiners were neither aware of the distribution of fit and misfit restorations in the sample, nor of the system or filter that was being shown. In order to analyze examiner reproducibility, 10% of the sample was reassessed.

Data Analysis

Time spent (TiS) in scoring an image ranged from 1 to 11464 s. From the pattern of time distribution, it may be interpreted that in some cases, an observer had left the image unfinished, and therefore time consumption was cut at the point where the continuous time distribution histogram became discontinuous. This was at 60 s, and therefore this time point was defined as the longest possible time spent with an image, which equaled 97.3%

of the conventional film assessments, 99.2% of the assessments for Digora system, 99.1% for VistaScan, and 98.5% for Express. The mean and standard deviation for TiS was calculated for each radiographic system. By ANOVA, TiS was compared among the filters within each radiographic system and restoration group. Also, the original digital images and the conventional radiographs were compared within the restoration group. Post hoc Tukey's tests were carried out where ANOVA indicated significance.

The traditional adjustment tools (zoom, gamma curve, brightness and contrast) were assessed based on the percentage of images where the examiner had used the tools.

Kappa index was used to analyze intra-examiner reproducibility of absolute scores (0,1,9). Regarding inter-observer agreement, the scores were compared between the examiners, two by two, and kappa index was also calculated.

Sensitivity, specificity and overall accuracy ([true positives + true negatives]/all scores) of each system, filter and restoration group were calculated for each examiner. The diagnostic accuracy parameters were calculated considering only the scores '0' and '1'. The answer 'I cannot decide' (score '9') was calculated and evaluated separately.

For the binary and multivariate logistic regression, a "mean examiner" accuracy was defined and used. The "mean examiner" score was calculated based on the raw scores, i.e. the most prevalent score among the four examiners [(score Ex1) ─ (score Ex2) ─ (score Ex3) ─ (score Ex4)]. From 2560 images analyzed, 207 cases had a tie among examiners' scores. The ties involving the scores '0' and '9' (e.g. 0─0─9─9), or '1' and '9' (e.g. 1─1─9─9) were assigned the score '0' or '1', respectively. For ties involving the scores '0' and '1' (e.g. 0─0─1─1), the incorrect (false) score was computed, whether it was a false positive or a false negative. The 16 images that had 'I cannot decide' as the "mean examiner" score were re-categorized as missing value, and therefore did not take part on the regression analyses.

The binary logistic regression evaluated whether time spent (TiS), restoration type, gap size, radiographic system, and filter had an impact on the overall accuracy, and those with an outcome ($p \leq 0.2$) were included in the multivariate model. The variable TiS was dichotomized in $\leq$ 10 / > 10 seconds (this threshold equaled > 50% of assessments for all systems). Multivariate logistic regression was then performed with the "mean examiner" accuracy as the dependent variable and the variables with an initial outcome ($p \leq 0.2$) as the independent variables.

Statistical analysis was performed with the software packages SPSS (version 13.0; IBM) and Excel 2010 (Microsoft Office). The level of statistical significance was $p < 0.05$.

RESULTS

A total of 2560 images were evaluated per examiner (2400 digital and 160 conventional). Overall, the digital images were assessed faster than the conventional radiographs. Most of the digital images were scored in less than 10 s, while the majority of conventional ones took longer than 10 s. For original images, the time spent when assessing digital images was significantly less than the time used for the conventional radiographs, for both restoration groups; further, examiners spent more time on Express images than on VistaScan images (Crown and MOD groups) and on Digora (MOD group). When original and filtered images were compared, the former ones were scored faster regardless of the digital system or the restoration group. Overall, examiners spent more time scoring high enhanced, inverted and pseudo 3D images on Digora, low enhanced on VistaScan and both low and high enhanced on Express systems (Crown group). The results for TiS are shown in Table 2.

The majority of the Digora and VistaScan images were assessed without any additional change (60% and 64.6%, respectively), while for the Express system, 54.7% received some adjustment. The gamma curve was the most used in all types of images. There was a trend that this tool was used more in the Crown group and in images with inversion and pseudo 3D filters.

A score ‘9’ was given in 6.2% of the whole sample. It ranged from 0.8% to 17.3% among the four examiners (0.8% for Ex4, 3.0% for Ex2, 3.9% for Ex3, and 17.3% for Ex1). The conventional images obtained 3.7% score ‘9’ and the original digital images 5.4% (Digora), 2.7% (VistaScan), and 5.0% (Express). When digital filtered images were analyzed, the high enhancement filter (9.1% for Digora, and 11.5% for VistaScan) and the pseudo 3D (10.7% for Express) had more score ‘9’. The Crown group (55,3%) had the highest number of score ‘9’ answers, independent of the type of image or system being evaluated.

Intra-observer reproducibility showed a moderate to good agreement (kappa ranged from 0.56 to 0.84). Even though one examiner (Ex2) had less experience with this type of dental diagnosis and therefore obtained lower kappa values, the values varied considerably independent of the examiners’ background experience (Table 3). Thus, the mean between observers is presented together with the range for each system and filter (Table 4). Overall, higher sensitivity, specificity and overall accuracy values associated with higher agreement among the examiners was seen in conventional radiographs and digital original images. The filtered digital images had both the highest and the lowest diagnostic validity, indicating variability among the answers. Considering the Crown group, the inversion and pseudo 3D images obtained the lowest sensitivity values, and the high enhancement filter images the lowest specificity values independent of the digital systems. In the MOD group, the inversion filter showed the poorest sensitivity. For the others filters, the sensitivities and specificities were higher or comparable with the Crown group.

From the results of the binary logistic regression analyses, only the radiographic system category was not included in the multivariate model, since the initial analysis did not reveal differences between the four systems' original images ($p = 0.663$). The results from the multivariate logistic regression analysis are shown in Table 5. The significant risk factors for an incorrect diagnosis were the restoration type (crowns were more often incorrectly diagnosed), and the gap size (a 0.2 mm misfit was more often incorrectly diagnosed). For the time spent assessing the image, observers who spent less time in the evaluation process had a higher chance of a correct score. Regarding the filters, the high enhancement ($p = 0.048$) and the inversion ($p = 0.020$) filter were statistically significantly related to a lower accuracy within the three digital systems.

DISCUSSION

A systematic review of the literature revealed few studies assessing the radiographic detection of a misfit between a coronal restoration and the dental hard tissue, and none have assessed the effect of post-processing of digital images. Two recent papers have suggested the presence of digital radiographic artifacts adjacent to metal restorations, which could impair the interpretation of such images.[15,19] Therefore, this study aimed to compare conventional and digital radiographic images, original and enhanced, to verify the diagnostic accuracy of metal MOD inlay and crown misfit. The first null hypothesis, that no significant difference would be found in the comparison between conventional and digital original images, was not rejected, but the second one, that no significant difference would be found in the comparison among the different post-processing filters, was rejected.

A 3-point scale was adopted, once it is believed that if a test results in many 'I cannot decide' answers, it means that this exam does now allow distinguishing between the categories of the "disease" assessed. The benefit of this score possibility was that the examiners were not supposed just to guess if in doubt. From a total of 2560 images analyzed per examiner, the percentage of the score '9' varied from 0.8% to 17.3% among the examiners. Even though the '9' score may influence the results of the diagnostic outcome (sensitivity, specificity, and overall accuracy) for the examiners individually, it also revealed which systems/filters brought more doubts during image interpretation. Besides, since the score for a "mean examiner" was calculated based on the most prevalent score among the four examiners and used for the performance of the logistic regression analysis, it may not be a bias for the main analysis of data. Then, when the "mean examiner" accuracy was evaluated, the answer 'I cannot decide' was given in only 16 cases, 14 in the Crown group, and nine comprising images with high enhancement filter, suggesting that this type of filter raised more doubt, and, therefore, its use should be avoided when metal restorations are present. Also, considering that there was an even number of examiners, the score calculation for the "mean examiner" accuracy took into account the presence of a tie among the answers of the four examiners. In those cases, the false score was assigned, and a false negative or false positive diagnosis was computed. This choice aimed to create the worst-case scenario for each answer, avoiding benefiting one or another type of image and obtaining an artificially high overall accuracy.

One of the main differences between conventional and digital radiographic methods is the possibility for post-processing the digital image. Processing involves a mathematical transformation of data in order to e.g. increase the contrast of relevant structures,[7,8] and it can be expected that the use of a task specific filter for post-processing of the digital radiographs may shorten the evaluation time of the images.[20] Even though the digital images were assessed faster than the conventional ones, more time was spent for assessment of filtered images than for the original ones. The filters chosen for this study were similar in function among the three digital systems studied, and so far dedicated software does not offer specific filters for the diagnostic task in question. Hence, the examiners were allowed to use traditional image adjustment ─ gamma, brightness, and contrast tools ─ as they wished. The association between the use of these tools and a correct diagnosis was not tested, since the exact moment when the examiners decided on a score could not be linked to the image adjustment. However, the fact that the examiners also used these tools suggests uncertainty with some of the filters.

Some studies have pointed out that enhanced images are preferred among observers,[21] and that the use of filters would be beneficial to some diagnostic tasks.[10-14] However, enhancing the edges by increasing the radiographic contrast may generate the appearance of a radiolucent line in the boundary of structures with high density difference known as rebound effect or “Uberschwinger”,[16,17] similar to the Mach band effect seen in conventional radiographs.[18] This phenomenon is predominantly seen adjacent to edges of metal restorations and may interfere with diagnosis, simulating tissue loss, mismatch adjacent to metallic materials or impeding lesion detection. The medical literature[16,17] has reported on the presence of this effect in digital chest radiographs after the use of filters for edge enhancement. So far, no study has systematically analyzed the rebound effect in dental radiographs.

A case report,[19] assessing periapical and bitewing radiographs, pointed out that the use of the enhancement mode in the digital system software (ClearVu; Dexis) could lead to interpretation doubts, but the authors did not measure how much this really interfered with the diagnosis compared with non-filtered images. In the present study, 80 teeth restored with a metal alloy, divided into a Crown and a MOD group, were assessed. This division into two groups aimed to evaluate the behavior of the metal when the location of the margin was adjacent to the enamel or to the cemento-enamel junction (i.e. adjacent to the root dentin), and how much the difference in density between these structures would influence the diagnosis. The results from the multivariate logistic regression showed a statistically significant difference between the MOD and the Crown groups. Even though a crown is a larger metal structure that could induce more interference in the image, the difference in density between the metal and the enamel is lower, suggesting also that the enamel induces less interference than the dentin in the radiograph, especially in digital images. Also, two levels of the enhancement filter – low and high – were selected as available in the software.

It is known that the mathematical matrix used for the various filters may differ according to software.[22,23] However, comparing the algorithms for data transformation was not an objective, but rather comparing the available possibilities in manufacturers' distributed software. The comparison among the filters within each digital system in the multivariate logistic regression showed more incorrect diagnoses for the high enhancement and the inversion filters independent of the digital system.

Sensitivity, specificity, and overall accuracy are properties of a diagnostic method that should be taken into account when deciding whether or not to use the method under evaluation. The outcomes of this study showed higher specificity than sensitivity for the radiographic examination, independent of the image group being evaluated. Conventional radiographs and the original digital images showed a tendency for a narrower range for sensitivity, specificity and accuracy values among the examiners, suggesting that non-filtered images should be preferred when evaluating teeth with metal restorations. Also, in spite of the lower resolution of images from the Express system, the binary logistic regression analyses did not reveal differences between the four systems' original images ($p = 0.663$). The higher sensitivity seen for the images with high enhancement filter was accompanied by the highest number of false positive diagnoses among all systems, which may be explained by the exacerbation of the rebound effect by the enhancement filter. On the other hand, the inversion and pseudo 3D filters had the lowest sensitivity together with the highest specificity, suggesting that they could be used together with a clinical examination, not resulting in a high risk for a false positive outcome.

The values of sensitivity, specificity and overall accuracy revealed a wide variation of results among the examiners, especially when filtered images were under evaluation. Haak *et al*,[24] compared conventional and digital images for the detection of misfits in composite Class II fillings and also found a wide variation among examiners. This finding suggests that the radiographic examination should be used together with the clinical information for treatment decision. However, in some population studies there is no access to a clinical examination, and in those situations the results are based solely on the radiographic findings.[25-29] Furthermore, also in epidemiological studies, there is a trend to replace conventional film with digital images.[30,31] Regarding the evaluation of teeth with metal restorations, the higher performance seen with the original digital radiographs suggests that the image requested for population surveys should be without any post-processing filter.

CONCLUSIONS

The detection of marginal gaps associated with metal restorations was not affected by the radiographic system (conventional or digital), but was related to the use of different filters available in the digital software systems. Marginal gaps were easier to diagnose in connection with MOD inlays than with crowns. Original images should be preferred for the assessment of teeth with metal restorations, considering their higher accuracy, and particularly high enhancement filters and inversion should be avoided in digital images, especially when metal crowns are present.

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REFERENCES

1. Sorensen SE, Larsen IB, Jorgensen KD. Gingival and alveolar bone reaction to marginal fit of subgingival crown margins. Scand J Dent Res 1986;94:109-14.

2. Mjor IA. Clinical diagnosis of recurrent caries. J Am Dent Assoc 2005;136:1426-33.

3. Ozbas H, Asci S, Aydin Y. Examination of the prevalence of periapical lesions and technical quality of endodontic treatment in a Turkish subpopulation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2011;112:136-42.

4. Papageorgiou SN, Papadelli AP, Koidis PT, Petridis HP. The effect of prosthetic margin location on caries susceptibility. A systematic review and meta-analysis. Br Dent J 2013;214:617-24.

5. van der Stelt PF. Better imaging: the advantages of digital radiography. J Am Dent Assoc 2008;139 Suppl:7S-13S.

6. Wenzel A. Computer-aided image manipulation of intraoral radiographs to enhance diagnosis in dental practice: a review. Int Dent J 1993;43:99-108.

7. Analoui M. Radiographic image enhancement. Part I: spatial domain techniques. Dentomaxillofac Radiol 2001;30:1-9.

8. Analoui M. Radiographic digital image enhancement. Part II: transform domain techniques. Dentomaxillofac Radiol 2001;30:65-77.

9. Wenzel A, Hintze H. Perception of image quality in direct digital radiography after application of various image treatment filters for detectability of dental disease. Dentomaxillofac Radiol 1993;22:131-4.

10. Moystad A, Svanaes DB, Risnes S, Larheim TA, Grondahl HG. Detection of approximal caries with a storage phosphor system. A comparison of enhanced digital images with dental X-ray film. Dentomaxillofac Radiol 1996;25:202-6.

11. Svanaes DB, Moystad A, Larheim TA. Approximal caries depth assessment with storage phosphor versus film radiography. Evaluation of the caries-specific Oslo enhancement procedure. Caries Res 2000;34:448-53.

12. Hadley DL, Replogle KJ, Kirkam JC, Best AM. A comparison of five radiographic systems to D-speed film in the detection of artificial bone lesions. J Endod 2008;34:1111-4.

13. de Azevedo Vaz SL, Neves FS, Figueiredo EP, Haiter-Neto F, Campos PS. Accuracy of enhancement filters in measuring in vitro peri-implant bone level. Clin Oral Implants Res 2013;24:1074-7.

14. Kal BI, Baksi BG, Dundar N, Sen BH. Effect of various digital processing algorithms on the measurement accuracy of endodontic file length. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103:280-4.

15. Brettle D, Carmichael F. The impact of digital image processing artefacts mimicking pathological features associated with restorations. Br Dent J 2011;211:167-70.

16. Oestmann JW, Prokop M, Schaefer CM, Galanski M. Hardware and software artifacts in storage phosphor radiography. Radiographics 1991;11:795-805.

17. Foster DR. Miliary tuberculosis following intravesical BCG treatment. Br J Radiol 1997;70:429.

18. Nielsen CJ. Effect of scenario and experience on interpretation of mach bands. J Endod 2001;27:687-91.

19. Schweitzer DM, Berg RW. A digital radiographic artifact: A clinical report. J Prosthet Dent 2010;103:326-9.

20. Haak R, Wicht MJ, Noack MJ. Conventional, digital and contrast-enhanced bitewing radiographs in the decision to restore approximal carious lesions. Caries Res 2001;35:193-9.

21. Wenzel A, Haiter-Neto F, Gotfredsen E. Risk factors for a false positive test outcome in diagnosis of caries in approximal surfaces: impact of radiographic modality and observer characteristics. Caries Res 2007;41:170-6.

22. Haiter-Neto F, Casanova MS, Frydenberg M, Wenzel A. Task-specific enhancement filters in storage phosphor images from the Vistascan system for detection of proximal caries lesions of known size. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;107:116-21.

23. Haiter-Neto F, dos Anjos Pontual A, Frydenberg M, Wenzel A. Detection of non-cavitated approximal caries lesions in digital images from seven solid-state receptors with particular focus on task-specific enhancement filters. An ex vivo study in human teeth. Clin Oral Investig 2008;12:217-23.

24. Haak R, Wicht MJ, Hellmich M, Noack MJ. Detection of marginal defects of composite restorations with conventional and digital radiographs. Eur J Oral Sci 2002;110:282-6.

25. Tsuneishi M, Yamamoto T, Yamanaka R, Tamaki N, Sakamoto T, Tsuji K, et al. Radiographic evaluation of periapical status and prevalence of endodontic treatment in an

adult Japanese population. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2005;100:631-5.

26. Kirkevang LL, Vaeth M, Wenzel A. Prevalence and incidence of caries lesions in relation to placement and replacement of fillings: a longitudinal observational radiographic study of an adult Danish population. Caries Res 2009;43:286-93.

27. Kirkevang LL, Vaeth M, Wenzel A. Incidence of caries lesions in approximal surfaces: a radiographic study of a general adult Danish population. Caries Res 2011;45:538-46.

28. Vizzotto MB, Rosing CK, de Araujo FB, Silveira HE. Radiographic evaluation of alveolar bone height in the primary dentition: a retrospective follow-up study. Pediatr Dent 2011;33:312-5.

29. Bahrami G, Vaeth M, Isidor F, Wenzel A. Marginal bone loss over 5 years in an adult Danish population. Oral Health Prev Dent 2007;5:113-8.

30. Kuonen P, Huynh-Ba G, Krummen VS, Stossel EM, Rothlisberger B, Salvi GE, et al. Restoration margins in young adolescents: a clinical and radiographic study of Swiss Army recruits. Oral Health Prev Dent 2009;7:377-82.

31. Jacobs R, Pittayapat P, van Steenberghe D, De Mars G, Gijbels F, Van Der Donck A, et al. A split-mouth comparative study up to 16 years of two screw-shaped titanium implant systems. J Clin Periodontol 2010;37:1119-27.

Table 1 Radiographic systems included

System	Kodak	Digora	VistaScan	Express
Receptor type	Conventional film (F-speed)	Phosphor plate	Phosphor plate	Phosphor plate
Company	Eastman Kodak	Soredex Orion Corporation	Dürr Dental	Instrumentarium
Dental unit	Spectro 70X Seletronic (Dabi Atlante), 70kV, 8mA	Heliodent 60B (Siemens) 60kV, 10mA	Spectro 70X Seletronic (Dabi Atlante), 70kV, 8mA	Focus (Instrumentarium), 70kV, 7mA
Exposure time (s)	0.5	0.4	0.6	0.4
Matrix		1034 x 1368	1608 x 1244	775 x 1025
Receptor resolution (line pairs / mm)	20	17	22	14.3
Image resolution (dpi)		635	1011	397
Filter function (name in software)	na	Enhancement low (Enhancement 15) Enhancement high (Enhancement 31) Inversion (Negative) Pseudo 3D (Emboss)	Enhancement low (Fine) Enhancement high (Caries 1) Inversion (Invert gray scale) Pseudo 3D (Emboss)	Enhancement low (Sharpen1) Enhancement high (Sharpen 2) Inversion (Invert gray scale) Pseudo 3D (Emboss)

na= not applicable.

Table 2 Time spent (TiS) scoring each type of image (mean ± SD, s)

Restoration group	Filter	System			
		Conventional	Digora	VistaScan	Express
Crown	OR	15.9 ± 13.6[C]	6.7 ± 8.4 [A,B a,b]	5.7 ± 7.0[A a]	8.0 ± 9.2[B a]
	LoE	na	6.1 ± 6.8[a]	8.0 ± 7.6[b]	10.8 ± 10.6[b]
	HiE	na	8.2 ± 12.4[b]	7.3 ± 8.4[a,b]	10.3 ± 11.9[b]
	IN	na	8.7 ± 10.1[b]	6.6 ± 9.7[a,b]	7.9 ± 6.2[a]
	3D	na	8.6 ± 9.5[b]	6.0 ± 7.3[a]	7.9 ± 8.5[a]
MOD	OR	9.9 ± 9.3[C]	4.9 ± 6.7[A a]	5.4 ± 7.3[A a]	7.5 ± 9.2[B a]
	LoE	na	6.0 ± 7.8[a,b]	5.3 ± 6.0[a]	7.1 ± 8.9[a]
	HiE	na	5.2 ± 6.0[a]	5.9 ± 6.9[a]	6.0 ± 7.1[a]
	IN	na	4.9 ± 5.2[a]	7.7 ± 11.1[b]	7.1 ± 8.8[a]
	3D	na	6.8 ± 6.6[b]	5.8 ± 5.8[a]	9.9 ± 11.0[b]

OR=original image; LoE=low enhancement; HiE=high enhancement; IN=inversion; 3D=pseudo 3D; na=not applicable. Numbers followed by upper case letters indicate comparisons among systems, within each restoration group (for 'OR' row only); numbers followed by lower case letters indicate comparisons among filters within each digital system, and within each restoration group (columns). Different letters indicate the statistical difference at $p < 0.05$; ANOVA followed by Tukey's multiple comparison test.

Table 3 Inter-examiner kappa value range for each system and filter

System	Filter	Crown	MOD
Conv	OR	0.51 – 0.81	0.49 – 0.75
Digora	OR	0.41 – 0.75	0.40 – 0.83
	LoE	0.33 – 0.51	0.49 – 0.71
	HiE	0.25 – 0.50	0.53 – 0.88
	IN	0.46 – 0.63	0.41 – 0.72
	3D	0.24 – 0.77	0.20 – 0.73
VistaScan	OR	0.52 – 0.86	0.50 – 0.76
	LoE	0.50 – 0.90	0.52 – 0.85
	HiE	0.35 – 0.94	0.57 – 0.74
	IN	0.46 – 0.90	0.26 – 0.60
	3D	0.46 – 0.92	0.31 – 0.67
Express	OR	0.38 – 0.77	0.31 – 0.85
	LoE	0.20 – 0.64	0.59 – 0.82
	HiE	0.17 – 0.70	0.41 – 0.76
	IN	0.43 – 0.84	0.20 – 0.79
	3D	0.46 – 0.82	0.24 – 0.88

OR=original image; LoE=low enhancement; HiE=high enhancement; IN=inversion; 3D=pseudo 3D.

Table 4 Mean sensitivity, specificity, and accuracy, and range among the four examiners for each radiographic system and filter

System	Filter	Sensitivity				Specificity				Accuracy			
		Crown		MOD		Crown		MOD		Crown		MOD	
		Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range	Mean	Range
Conv	OR	0.76	0.62 – 0.87	0.81	0.65 – 1.00	0.84	0.68 – 0.95	0.90	0.83 – 0.93	0.81	0.71 – 0.87	0.86	0.79 – 0.91
Digora	OR	0.65	0.51 – 0.81	0.77	0.55 – 1.00	0.81	0.65 – 0.95	0.96	0.85 – 1.00	0.73	0.70 – 0.78	0.87	0.78 – 0.94
	LoE	0.76	0.56 – 1.00	0.83	0.70 – 0.97	0.76	0.48 – 0.90	0.85	0.65 – 0.95	0.80	0.73 – 0.88	0.85	0.83 – 0.88
	HiE	0.77	0.64 – 0.85	0.85	0.63 – 1.00	0.55	0.40 – 0.61	0.95	0.90 – 1.00	0.64	0.59 – 0.74	0.88	0.79 – 1.00
	IN	0.52	0.33 – 0.82	0.59	0.36 – 0.94	0.93	0.86 – 1.00	0.98	0.95 – 1.00	0.73	0.67 – 0.84	0.79	0.68 – 0.96
	3D	0.49	0.36 – 0.69	0.69	0.55 – 0.89	0.90	0.83 – 0.97	0.93	0.85 – 1.00	0.70	0.60 – 0.85	0.81	0.70 – 0.90
VistaScan	OR	0.70	0.49 – 0.83	0.83	0.73 – 1.00	0.92	0.85 – 0.98	0.88	0.72 – 0.95	0.81	0.73 – 0.87	0.86	0.83 – 0.90
	LoE	0.76	0.58 – 0.88	0.85	0.73 – 0.97	0.85	0.75 – 0.95	0.84	0.73 – 0.92	0.81	0.76 – 0.87	0.85	0.81 – 0.87
	HiE	0.82	0.55 – 1.00	0.85	0.73 – 1.00	0.69	0.53 – 0.85	0.92	0.80 – 1.00	0.77	0.70 – 0.86	0.90	0.84 – 0.94
	IN	0.64	0.36 – 0.85	0.61	0.26 – 1.00	0.97	0.95 – 1.00	0.96	0.88 – 1.00	0.81	0.68 – 0.93	0.84	0.65 – 1.00
	3D	0.65	0.45 – 0.76	0.70	0.45 – 0.97	0.94	0.85 – 1.00	0.93	0.82 – 0.98	0.80	0.71 – 0.88	0.81	0.71 – 0.96
Express	OR	0.67	0.48 – 0.75	0.79	0.46 – 0.97	0.91	0.85 – 1.00	0.89	0.72 – 1.00	0.79	0.69 – 0.89	0.84	0.73 – 0.94
	LoE	0.74	0.47 – 1.00	0.91	0.85 – 1.00	0.77	0.61 – 0.84	0.88	0.78 – 0.95	0.76	0.67 – 0.79	0.90	0.86 – 0.95
	HiE	0.77	0.49 – 1.00	0.89	0.70 – 1.00	0.60	0.41 – 0.82	0.80	0.65 – 0.95	0.69	0.65 – 0.72	0.85	0.83 – 0.89
	IN	0.64	0.38 – 0.85	0.72	0.28 – 0.97	0.93	0.90 – 0.97	0.91	0.73 – 1.00	0.79	0.66 – 0.91	0.81	0.64 – 0.96
	3D	0.59	0.39 – 0.74	0.70	0.42 – 0.91	0.93	0.86 – 1.00	0.90	0.70 – 0.98	0.76	0.67 – 0.86	0.80	0.71 – 0.94

OR=original image; LoE=low enhancement; HiE=high enhancement; IN=inversion; 3D=pseudo 3D.

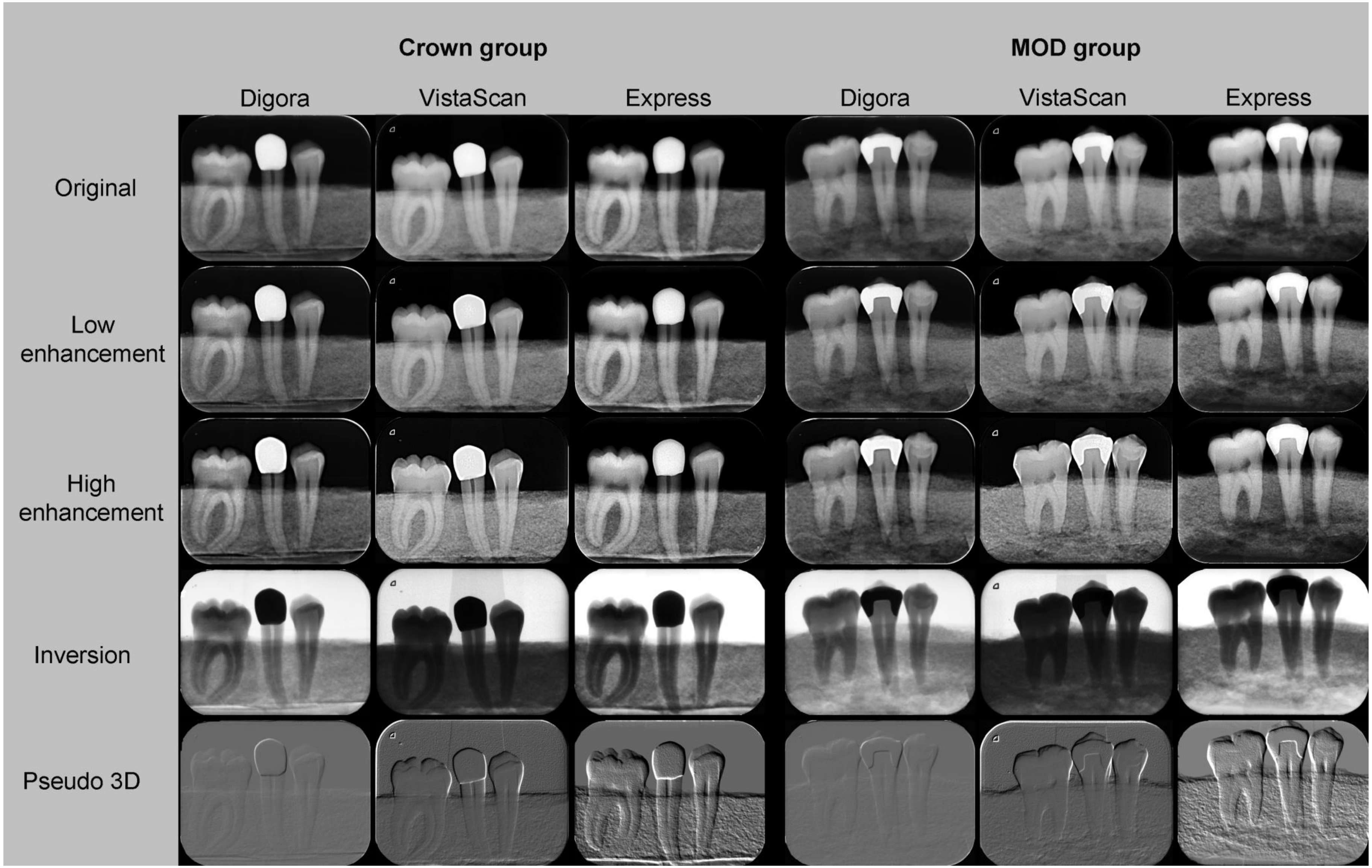
Table 5 Multivariate logistic regression analysis with "mean examiner" accuracy as the dependent variable

	p value	Odds ratio	95% CI
Time (> 10 s)			
≤ 10 s	< 0.001	2.903	2.307 – 3.653
Restoration (MOD)			
Crown	< 0.001	0.613	0.492 – 0.763
Gap size (0 mm)			
0.2 mm	< 0.001	0.133	0.104 – 0.171
0.4 mm	0.002	0.617	0.457 – 0.833
Filter (original)			
Low enhancement	0.579	0.910	0.652 – 1.270
High enhancement	0.048	0.720	0.520 – 0.997
Inversion	0.020	0.682	0.494 – 0.942
Pseudo 3D	0.293	0.839	0.604 – 1.164

p value, odds ratio and 95% confidence interval (CI) for the independent variables: time spent, restoration type, gap size and filter (the group in brackets is the reference group).

Fig. 1. Digital original images of teeth in the Crown group and in the MOD group with fit and misfit restorations. The upper rows show a pair, fit+0.2 mm misfit, and the bottom rows show a pair, fit+0.4 mm misfit

Fig. 2. Original and filtered images in a tooth with a fit crown and a tooth with a fit MOD inlay



ARTIGO 3

Influence of reconstruction thickness in the diagnostic performance of CBCT images in the presence of metal materials

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Abstract

Objective: To evaluate the post-processing of CBCT images using diverse reconstruction thicknesses, which may reduce metal artifacts and allow misfit detection adjacent to metal restorations.

Methods: Forty teeth with MOD inlay restorations (MOD group) and 40 with crowns (Crown group), each with 40 perfectly fit and 40 misfit restorations (20 - 0.2 mm gap, and 20 - 0.4 mm gap), were scanned with i-CAT Next Generation. Data were exported in DICOM format and dedicated software was used for image reconstruction in five thicknesses – 0.2 mm (voxel size), 1.0 mm, 2.0 mm, 5.0 mm, and 10.0 mm. Four examiners assessed the images for the presence of gaps using a 5-point scale ('there is no misfit', 'almost sure there is no misfit' 'cannot decide' 'almost sure there is a misfit' 'there is a misfit'). The area under the ROC curve (aucROC) with the respective confidence interval (CI) was calculated for each variable. A multivariate logistic regression was performed with accuracy as the dependent variable.

Results: The score 'cannot decide' decreased with the increase of the reconstruction thickness of the image (range: 12.19% to 1.25%). Mean aucROC ranged from 0.60 to 0.72. The analysis of the 95% CI showed the lower bound of the curve bellow or very close to the reference line. Logistic regression showed that the presence of a gap, independently of the size ($p < 0.001$), and the reconstruction thickness had a statistically significant impact on accuracy ($p < 0.05$).

Conclusions: Examiners demonstrated a weak performance to discriminate between fitted and no-fitted restorations in metal-restored teeth based on CBCT images. Increasing

the reconstruction thickness decreased examiner's doubt but did not increase diagnosis accuracy.

Statement of Clinical Relevance: Although changing reconstruction thickness may decrease metal artifacts seen in CBCT images, and therefore decreasing examiner's doubt in establishing a diagnosis, this procedure do not increase diagnosis accuracy in those situations.

Introduction

The development of cone beam computed tomography (CBCT) significantly increased the referral for three-dimensional examination in dentistry.[1,2] At the same time, it is important to optimize the use of the acquired volumetric data, which should undergo a thorough radiological report, aiming to keep the patient radiation exposure as low as reasonably achievable (ALARA principle).[3,4] Therefore, some diagnostic tasks that normally would not require a tomographic examination started to be evaluated.

In this sense, although there is no direct indication for this task, studies aimed to assess the diagnosis of dental caries by CBCT images, and some found an equivalence of diagnostic performance compared to conventional and/or digital radiography.[5-8] The overall evaluation of the quality of filling and crowns fitting is also important for the maintenance of the tooth and surrounding tissues, since it may lead to periodontal disease or recurrent caries. [9-11] Nevertheless, in case of metal restorations, the presence of metal affects image quality, which may jeopardize the accuracy of CBCT scans.[12] However, the above mentioned studies evaluated teeth without metal restorations, which may have contributed to the high sensitivity of CBCT found by some authors, since the presence of metal is detrimental for the image.

In an attempt to reduce the appearance of artifacts in the tomographic image some strategies have been developed, especially regarding data manipulation after its acquisition, such as applying a smooth filter or increasing the thickness of the displayed image.[13] Therefore, the purpose of this study was to evaluate the post-processing of CBCT images using diverse reconstruction thicknesses, which may reduce metal artifacts and allow misfit detection adjacent to metal restorations.

Material and methods

Preparation of teeth and restorations

This study was approved by the Ethics Committee in Research from the Institution (n. 225.034). Eighty extracted sound premolar human teeth were selected for the study (test teeth) and prepared to receive a mesio-ocluso-distal inlay (n = 40; MOD group), or a full crown (n = 40; Crown group). A 1.4 mm diameter tapered flat end burr (KG Sorensen, Barueri, Brazil) was used to prepare the teeth. The gingival floor of the MOD inlays was located 1.5 mm coronal to the cemento-enamel junction, and the crown margins were located at the cemento-enamel junction. Each tooth was waxed up twice: the first time with the restoration perfectly adapted to the preparation margins, and on the second time with a gap of either 0.2 mm or 0.4 mm (20 teeth with each gap size). The waxes were vacuum-invested and the MOD inlays or crowns were cast. Thus, two metal alloy (V-Fit Cast Ni-Cr; Talmax, Curitiba, Brazil) restorations with different marginal adaptation were made for each tooth in both the MOD and the Crown group. The proximal extent of the gaps was checked with a digital caliper (Cen-Tech, CA, EUA) under 10x magnification (MU-M19, D.F. Vasconcellos, Rio de Janeiro, Brazil). The restorations were not cemented, but smoothly placed in position.

Tomography of teeth with restorations

Each test tooth was allocated in plastic blocks, with a type III stone plaster (Herodent, Vigodent, Rio de Janeiro, Brazil) and sawdust mixture to simulate alveolar bone and to allow that their position be kept during all tomographic examinations. A pair of sound teeth (non-test teeth), consisting of a premolar and a molar, was used to secure approximal contacts.

The tooth blocks were placed on the tomography device (i-CAT Next Generation, Imaging Science International, Inc., Hatfield, PA, USA), six at a time, and scanned with a 16 x 13 cm FOV, and a 0.2 mm voxel resolution protocol (120kVp, 37.07 mA, 26.9 s). Data were exported in DICOM format and specific software (OnDemand 3D 1.0.7.0295; Cybermed, Seoul, South Korea) was used for image reconstruction. The contrast of the images was previously adjusted regarding the center level (L) and band-width (W) (L: 667; W: 3086). The test tooth was aligned with the long axis perpendicular to the ground, and five two-dimensional images with varying thicknesses – 0.2 mm (voxel size), 1.0 mm, 2.0 mm, 5.0 mm, and 10.0 mm – were generated, and saved in the bmp (bitmap) format (resolution of 96 dpi). The images were based on the mid coronal section of the teeth, resembling a periapical radiograph. Figure 1 shows the reconstruction thickness evaluated in four pairs of teeth, one representing each restoration group and gap size.

Images were assessed on a 22-inch flat screen monitor (Lenovo L2250pwD, Morrisville, USA, and AOC, Taipei, Taiwan), in a room with subdued light. Dedicated software (UniscoreL, designed by senior programmer Erik Gotfredsen, School of Dentistry, University of Aarhus, Denmark) was used to display the images in full size, 1:1 on the monitor, in a blinded and random sequence; the use of the zoom, gamma curve, brightness and contrast tools was not allowed.

Four examiners (two third-year PhD students in oral radiology – Ex1 and Ex2, one PhD in oral radiology – Ex3, and one first-year PhD student in oral radiology – Ex4, all dentists) performed the analysis of the images. The assessment of the images for the presence of marginal gaps was based on a five-point scale (score '1' = I am sure there is no misfit, score '2' = I am almost sure there is no misfit, but I would like an intraoral radiograph, score '3' = I cannot decide and I would like an intraoral radiograph, score '4' = I am almost sure there is a misfit, but I would like an intraoral radiograph, and score '5' = I am sure there is a misfit). In order to analyze the examiners reproducibility, 10% of the sample was reassessed.

Data Analysis

Kappa index was used to analyze intra- and inter-examiner reproducibility. A re-categorized dichotomous scale was used, where the scores '1', '2' and '3' were pooled together as "new score '0'", and scores '4' and '5' were pooled together as "new score '1'". Regarding inter-observer agreement, the scores were compared between the examiners, two by two.

The area under the ROC (receiver operating characteristics) curve with the respective 95% confidence interval (CI) of each reconstruction thickness and restoration group were calculated for each examiner.

For the binary and multivariate logistic regression, a “mean examiner” accuracy based on a 3-point scale was defined, where the scores ‘1’, ‘2’ were pooled together as “new score ‘0’, scores ‘4’ and ‘5’ were pooled together as “new score ‘1’ and scor ‘3’ remained unchanged representing the doubt, and used. The “mean examiner” score was calculated based on the raw scores, i.e. the most prevalent score among the four examiners [(score Ex1) ─ (score Ex2) ─ (score Ex3) ─ (score Ex4)]. From 800 images analyzed, 89 cases had a tie among examiners’ scores. The ties involving the scores ‘0’ and ‘3’ (e.g. 0─0─3─3), or ‘1’ and ‘3’ (e.g. 1─1─3─3) were assigned the score ‘0’ and ‘1’, respectively. For ties involving the scores ‘0’ and ‘1’ (e.g. 0─0─1─1), the incorrect (false) score was computed, whether it was a false positive or a false negative. The 15 images that had ‘I cannot decide’ as the “mean examiner” score were re-categorized as missing value, and therefore did not take part on the regression analyses.

The binary logistic regression evaluated whether restoration type, gap size, and reconstruction thickness had an impact on the overall diagnostic accuracy. Multivariate logistic regression was then performed with the “mean examiner” accuracy as the dependent variable and the significant variables as the independent variables (those with an outcome ($p \leq 0.2$) selected from the binary logistic regression).

Statistical analysis was performed with the software packages SPSS (version 13.0, SPSS, Chicago, IL, USA) and Microsoft Office Excel (Redmond, Washington, USA). The level of statistical significance was $p < 0.05$.

Results

Each examiner evaluated a total of 800 images. Table 1 shows the distribution examiners' answers among the 5 available scores. The frequency of score '1' had the higher change among the reconstructions evaluated, and increased with the increase of the reconstruction thickness. Score '3' ('I cannot decide') was given in 6.2% of the whole sample, and it decreased with the increase of image reconstruction thickness (range: 12.19% to 1.25%). Intra and inter-observer reproducibility showed a slight to moderate agreement, independent of the reconstruction thickness evaluated (Table 2).

Table 3 shows mean (0.60 – 0.72) and range (0.53 – 0.74) of area under the ROC curve (aucROC) and 95% confidence interval (CI) also for each reconstruction thickness and restoration group. It is possible to observe lower values with the increase of image reconstruction thickness. Moreover, the analysis of the 95% CI suggest a weak performance of the tomographic images to discriminate between fitted and no-fitted restorations, since the lower bound of the curves are bellow or very close to the reference line. Also, the values found between the two restoration groups were similar, suggesting no difference in evaluating MOD inlays or crowns.

All variables were included in the multivariate logistic model and the results are shown in Table 4. The significant risk factors for an incorrect diagnosis were the presence of a gap, independently of the size ($p < 0.001$), and the reconstruction thickness (increasing of the reconstruction thickness decreased the accuracy of the diagnosis). Reconstructions thicknesses of 5.0 mm ($p = 0.022$) and 10.0 mm ($p = 0.007$) showed a statistically significantly lower accuracy within the five image thickness assessed, and the voxel size image (0.2 mm) was shown as the best selection for examination.

Discussion

It is extremely important that the patient's benefits from a radiographic examination should be balanced against the risks of exposure to ionizing radiation. In the case of a tomographic evaluation, where the radiation dose is much higher than when traditional two-dimensional imaging methods are used, this principle is even clearer (especially when larger FOVs are employed). Consequently, the CBCT scan should be optimized to reach all the diagnosis the patient may need. Therefore, this study employed a large FOV, and the standard resolution for the CBCT unit used, simulating a patient with a requirement for scanning both arches. Thus, having in mind the recommended principles for justification and optimization,[4] it would be worthy that all the diagnosis tasks needed could be done based on the CBCT scan.

The use of radiographs to better assess restored proximal surfaces seems to be a consensus in the literature.[9,14] One article dealing with CBCT diagnosis of mechanically-created secondary caries found a better diagnostic performance with CBCT images than with bitewing radiographs.[15] However, they evaluated defects of 1.4 mm in diameter, which were much bigger than those of the present study (0.2 and 0.4 mm), which probably increased the sensibility of the exam. In the present study, the values of aucROC (0.60 ─ 0.72) for the tomographic assessment were low, indicating a weak ability to diagnose a misfit, and suggesting the need of an intraoral radiograph for this type of assessment.

Several studies address the issue of dealing with metal materials when evaluating different diagnostic tasks on CBCT images.[16,17] Metal materials can cause beam hardening, scatter effects, and photon starvation, which affect how the detector receives the signal after the exposure.[18,19] The photons of the X-ray beam exhibit a certain spectrum of energy, and photons with low energy are absorbed, especially by metal structures, while the high energy ones are not attenuated, resulting in beam hardening artifacts.[18,20] Scattered photons causes X-ray photons to change direction, and thus end up in a different detector, increasing this detector signal, and resulting in dark streaks.[21] In the case of photon starvation, no photons are detected, resulting in dark streaks, since zero must be replaced by a nonzero number of photons.[18] Some attempts to reduce this inconvenience have been proposed, such as use of higher kVp and/or mA, appliance of filtering algorithms, or changing the reconstruction thickness.[13,18,20] This study approached the reconstruction thickness variation, since this procedure does not involve re-exposure of the patient, and can be performed by any dedicated CBCT reconstruction software, not requiring specific post processing tools. Thus, reconstructions from the voxel size increasing up to the thickness of the dental crown, simulating the image as seen in an intraoral radiograph, were defined. The results showed that the increase in reconstruction thickness decreased examiner's doubt in establishing a diagnosis (decreasing in 'I cannot decide' score), probably due the decrease in the amount of artifact seen in the image.

The distribution of answers among the 5-point scale showed that the scores '1' and '2' (absence of misfit) were always higher than the scores '4' and '5' (presence of misfit), in spite of the reconstruction thickness. One could think that, since metal materials create streaking artifacts which may mimic or hide adjacent defects, the examiner would give a negative diagnosis for misfit upon a hypodense line adjacent to metal. This would avoid false positive results. Another hypothesis to explain the results observed lies on the spatial resolution, expressed by the number of line pairs (lp/mm) existent in an image. In the case of intraoral radiographic images the number of line pairs lies between five and 20 for most of the systems,[22] while for CBCT devices the actual spatial resolution was found to be < 3 lp/mm.[23] Moreover, in reconstructing a tomographic image, the process of adding multiple scans acquisitions considers the mean value of each section, and therefore may mask hypodense areas when superimposing hyperdense ones (Figure 2). Therefore, at the same time that it helps to minimize the effect of streaking artifacts, it sums blurring in the image, which could have also masked the presence of the gap and led the examiner to give a negative diagnosis. Thus, a 10 mm CBCT reconstruction may look like an intraoral radiograph, which is a projection the examiner is more used to work with, and has more experience in performing such diagnostic task. However, the process of acquisition and processing of tomographic images do not allow a reliable representation of the actual condition of the relation between the tooth surface and the metal material. Therefore, the results from the present study demonstrate that professionals should not rely on thick reconstructions for diagnosis adjacent to metal materials.

In conclusion, examiners demonstrated a weak performance to discriminate between fitted and non-fitted restorations in metal-restored teeth based on CBCT images, in spite of the reconstruction thickness used. Increasing in reconstruction thickness in CBCT images decreased the examiner's doubt but did not increase diagnosis accuracy.

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References

1. De Vos W, Casselman J, Swennen GR. Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: a systematic review of the literature. Int J Oral Maxillofac Surg. 2009;38:609-625.

2. Dobbyn LM, Morrison JF, Brocklebank LM, Chung LL. A survey of the first 6 years of experience with cone beam CT scanning in a teaching hospital orthodontic department. J Orthod. 2013;40:14-21.

3. Farman AG. ALARA still applies. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2005;100:395-397.

4. Project S-C. Radiation protection n° 172: Cone Beam CT for dental and maxillofacial radiology. Luxembourg: European Commission Directorate-General for Energy; 2012.

5. Akdeniz BG, Grondahl HG, Magnusson B. Accuracy of proximal caries depth measurements: comparison between limited cone beam computed tomography, storage phosphor and film radiography. Caries Res. 2006;40:202-207.

6. Haiter-Neto F, Wenzel A, Gotfredsen E. Diagnostic accuracy of cone beam computed tomography scans compared with intraoral image modalities for detection of caries lesions. Dentomaxillofac Radiol. 2008;37:18-22.

7. Kalathingal SM, Mol A, Tyndall DA, Caplan DJ. In vitro assessment of cone beam local computed tomography for proximal caries detection. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007;104:699-704.

8. Tsuchida R, Araki K, Okano T. Evaluation of a limited cone-beam volumetric imaging system: comparison with film radiography in detecting incipient proximal caries. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007;104:412-416.

9. Mjor IA. Clinical diagnosis of recurrent caries. J Am Dent Assoc. 2005;136:1426-1433.

10. Papageorgiou SN, Papadelli AP, Koidis PT, Petridis HP. The effect of prosthetic margin location on caries susceptibility. A systematic review and meta-analysis. Br Dent J. 2013;214:617-624.

11. Sorensen SE, Larsen IB, Jorgensen KD. Gingival and alveolar bone reaction to marginal fit of subgingival crown margins. Scand J Dent Res. 1986;94:109-114.

12. Schulze R, Heil U, Gross D, Bruellmann DD, Dranischnikow E, Schwanecke U, et al. Artefacts in CBCT: a review. Dentomaxillofac Radiol. 2011;40:265-273.

13. Kataoka ML, Hochman MG, Rodriguez EK, Lin PJ, Kubo S, Raptopolous VD. A review of factors that affect artifact from metallic hardware on multi-row detector computed tomography. Curr Probl Diagn Radiol. 2010;39:125-136.

14. Kidd EA. Caries diagnosis within restored teeth. Adv Dent Res. 1990;4:10-13.

15. Charuakkra A, Prapayasatok S, Janhom A, Pongsiriwet S, Verochana K, Mahasantipiya P. Diagnostic performance of cone-beam computed tomography on detection of mechanically-created artificial secondary caries. Imaging Sci Dent. 2011;41:143-150.

16. da Silveira PF, Vizzotto MB, Liedke GS, da Silveira HL, Montagner F, da Silveira HE. Detection of vertical root fractures by conventional radiographic examination and cone beam computed tomography - an in vitro analysis. Dent Traumatol. 2013;29:41-46.

17. Sanders MA, Hoyjberg C, Chu CB, Leggitt VL, Kim JS. Common orthodontic appliances cause artifacts that degrade the diagnostic quality of CBCT images. J Calif Dent Assoc. 2007;35:850-857.

18. Boas FE, Fleischmann D. Evaluation of two iterative techniques for reducing metal artifacts in computed tomography. Radiology. 2011;259:894-902.

19. De Man B, Nuyts J, Dupont P, Marchal G, Suetens P. Metal Streak Artifacts in X-ray Computed Tomography: A Simulation Study. IEEE Transactions on Nuclear Science. 1999;46:691-696.

20. Draenert FG, Coppenrath E, Herzog P, Muller S, Mueller-Lisse UG. Beam hardening artefacts occur in dental implant scans with the NewTom cone beam CT but not with the dental 4-row multidetector CT. Dentomaxillofac Radiol. 2007;36:198-203.

21. Joseph PM, Spital RD. The effects of scatter in x-ray computed tomography. Med Phys. 1982;9:464-472.

22. Farman AG, Farman TT. A comparison of 18 different x-ray detectors currently used in dentistry. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2005;99:485-489.

23. Pauwels R, Beinsberger J, Stamatakis H, Tsiklakis K, Walker A, Bosmans H, et al. Comparison of spatial and contrast resolution for cone-beam computed tomography scanners. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012;114:127-135.

Table 1 Mean frequency (%) of score's answer among the four examiners for each reconstruction thickness (RT) and restoration group

Answer	RT 0.2 mm		RT 1.0 mm		RT 2.0 mm		RT 5.0 mm		RT 10.0 mm	
	Crown	MOD	Crown	MOD	Crown	MOD	Crown	MOD	Crown	MOD
1	23.13	19.06	21.25	19.06	26.88	25.00	30.31	45.31	59.38	53.44
2	30.63	27.19	37.19	26.25	32.50	27.50	32.81	34.38	16.56	24.38
3	12.19	7.50	8.44	7.50	8.13	8.75	3.13	3.44	1.88	1.25
4	24.38	27.81	21.56	28.13	22.19	25.00	26.25	13.75	14.69	15.31
5	9.69	18.44	11.56	19.06	10.31	13.75	7.50	3.13	7.50	5.94

1 = I am sure there is no misfit. 2 = I am almost sure there is no misfit, but I would like an intraoral radiograph. 3 = I cannot decide and I would like an intraoral radiograph. 4 = I am almost sure there is a misfit, but I would like an intraoral radiograph. 5 = I am sure there is a misfit.

Table 2 Intra and inter-examiner reproducibility (kappa range) for each restoration group and reconstruction thickness (RT)

Reproducibility	RT (mm)	Restoration group	
		Crown	MOD
Intra	na	0.52 – 0.69	0.12 – 0.81
Inter	0.2	0.37 – 0.56	0.26 – 0.57
	1.0	0.28 – 0.43	0.30 – 0.62
	2.0	0.44 – 0.51	0.31 – 0.57
	5.0	0.35 – 0.49	0.18 – 0.57
	10.0	0.17 – 0.37	0.24 – 0.62

na=not applicable

Table 3 Area under the ROC curve and 95% confidence interval for each reconstruction thickness (RT) and restoration group. The mean and range among the four examiners are shown

RT (mm)	Crown				MOD			
	aucROC		95% CI		aucROC		95% CI	
	Mean	Range	Lower bound	Upper bound	Mean	Range	Lower bound	Upper bound
0.2	0.64	0.62 – 0.69	0.50	0.80	0.71	0.69 – 0.73	0.57	0.84
1.0	0.65	0.62 – 0.68	0.50	0.80	0.72	0.68 – 0.74	0.56	0.86
2.0	0.62	0.53 – 0.67	0.40	0.79	0.71	0.69 – 0.73	0.57	0.84
5.0	0.63	0.57 – 0.70	0.44	0.82	0.64	0.60 – 0.69	0.48	0.81
10.0	0.60	0.54 – 0.69	0.41	0.80	0.62	0.59 – 0.69	0.46	0.80

Table 4 Multivariate logistic regression analysis with "mean examiner" accuracy as the dependent variable

	p value	Odds ratio	95% CI
Restoration (MOD)			
Crown	0.074	0.738	0.529 – 1.030
Gap size (0 mm)			
0.2 mm	< 0.001	0.057	0.036 – 0.088
0.4 mm	< 0.001	0.487	0.334 – 0.712
RT (mm) (0.2)			
1.0	0.285	0.744	0.432 – 1.280
2.0	0.071	0.607	0.353 – 1.043
5.0	0.022	0.534	0.312 – 0.912
10.0	0.007	0.481	0.282 – 0.821

RT= reconstruction thickness. *p* value, odds ratio and 95% confidence interval (CI) for the independent variables: restoration type, gap size and reconstruction thickness (RT) (the group in brackets is the reference group).

Figure 1 Reconstructed tomographic images (RT) of teeth in the Crown and in the MOD groups with fit and misfit restorations. The first two columns of each restoration group shows a pair fit+0.2 mm misfit, and the last two columns show a pair fit+0.4 mm misfit

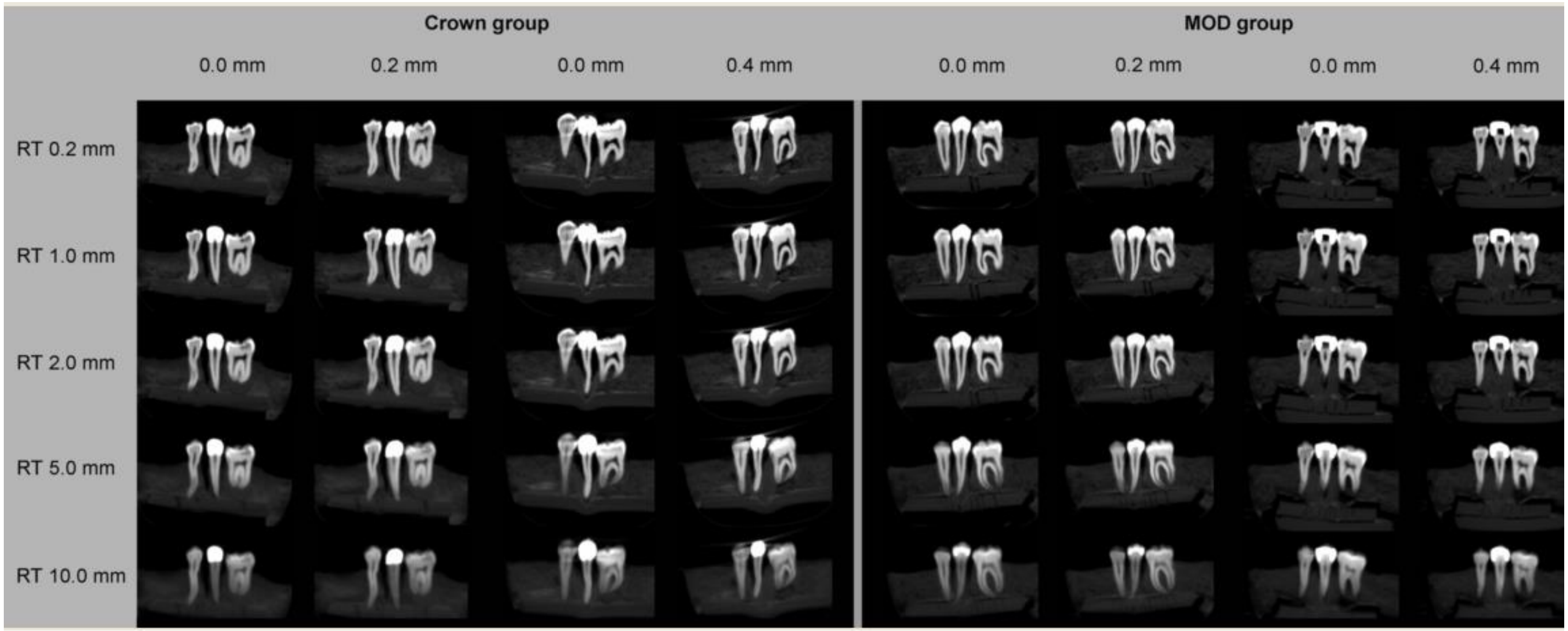
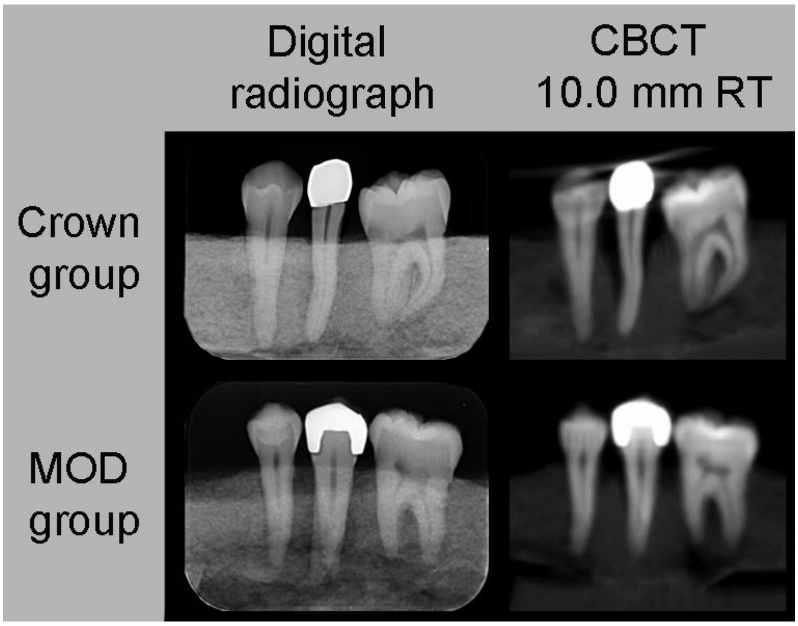


Figure 2 Digital radiographs and 10 mm reconstructed tomographic images of teeth in the Crown and in the MOD groups with a 0.4 mm misfit restorations.



3 CONSIDERAÇÕES FINAIS

A literatura é incisiva quanto à importância da avaliação da adaptação e integridade marginal de próteses e restaurações para a manutenção do elemento dentário e tecidos adjacentes. Ao mesmo tempo, recomenda cautela na avaliação clínica e/ou radiográfica. A radiografia digital vem substituindo o método convencional, devendo-se lembrar que o método digital é influenciado pelo pós-processamento da imagem, apresentando impacto direto na acurácia do diagnóstico do exame dependendo da estrutura avaliada. No caso da avaliação de restaurações metálicas, foi observado que filtros de realce de borda com alta penetrância devem ser evitados, considerando o risco do resultado falso-positivo pelo efeito rebote e visualização de linha radiolúcida adjacente ao metal. Nesses casos, então, a avaliação proximal deve ser realizada com base em imagens originais – convencionais ou digitais. O aumento na solicitação de exames tomográficos entre os dentistas fez aumentar a preocupação com a dose de radiação recebida pelos pacientes. Assim, é importante otimizar o volume adquirido e investigá-lo em toda sua extensão. Entretanto, a presença de materiais metálicos ainda representa um desafio para o diagnóstico tomográfico e a avaliação de restaurações metálicas demonstrou uma pobre acurácia para análise de adaptação proximal. Acredita-se que o desenvolvimento de novas tecnologias referentes ao método da TCFC possa superar a deficiência observada hoje com relação à interpretação tomográfica dos materiais metálicos.

REFERÊNCIAS

1. Sorensen SE, Larsen IB, Jorgensen KD. Gingival and alveolar bone reaction to marginal fit of subgingival crown margins. Scand J Dent Res. 1986; 94(2):109-14.

2. Felton DA, Kanoy BE, Bayne SC, Wirthman GP. Effect of in vivo crown margin discrepancies on periodontal health. J Prosthet Dent. 1991; 65(3):357-64.

3. Giollo MD, Valle PM, Gomes SC, Rosing CK. A retrospective clinical, radiographic and microbiological study of periodontal conditions of teeth with and without crowns. Braz Oral Res. 2007; 21(4):348-54.

4. Mjor IA. Clinical diagnosis of recurrent caries. J Am Dent Assoc. 2005; 136(10):1426-33.

5. Larson TD. The clinical significance of marginal fit. Northwest Dent. 2012; 91(1):22-9.

6. Papageorgiou SN, Papadelli AP, Koidis PT, Petridis HP. The effect of prosthetic margin location on caries susceptibility. A systematic review and meta-analysis. Br Dent J. 2013; 214(12):617-24.

7. Totiam P, Gonzalez-Cabezas C, Fontana MR, Zero DT. A new in vitro model to study the relationship of gap size and secondary caries. Caries Res. 2007; 41(6):467-73.

8. Cenci MS, Pereira-Cenci T, Cury JA, Ten Cate JM. Relationship between gap size and dentine secondary caries formation assessed in a microcosm biofilm model. Caries Res. 2009; 43(2):97-102.

9. Ozbas H, Asci S, Aydin Y. Examination of the prevalence of periapical lesions and technical quality of endodontic treatment in a Turkish subpopulation. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2011; 112(1):136-42.

10. Eidelman E, Fuks A, Chosack A. A clinical, radiographic, and SEM evaluation of Class 2 composite restorations in primary teeth. Oper Dent. 1989; 14(2):58-63.

11. Smith GP. The marginal fit of the full cast shoulderless crown. J Prosthet Dent. 1957; 7(2):231-43.

12. Spedding RH. Two principles for improving the adaptation of stainless steel crowns to primary molars. Dent Clin North Am. 1984; 28(1):157-75.

13. Kidd EA. Caries diagnosis within restored teeth. Adv Dent Res. 1990; 4(10-3.

14. Gilboa I, Cardash HS, Baharav H, Demko CA, Teich ST. A longitudinal study of the survival of interproximal root caries lesions restored with glass ionomer cement via a minimally invasive approach. Gen Dent. 2012; 60(4):e224-30.

15. van der Stelt PF. Better imaging: the advantages of digital radiography. J Am Dent Assoc. 2008; 139 Suppl(7S-13S.

16. Borg E, Grondahl K, Grondahl HG. Marginal bone level buccal to mandibular molars in digital radiographs from charge-coupled device and storage phosphor systems. An in vitro study. J Clin Periodontol. 1997; 24(5):306-12.

17. Friedlander LT, Love RM, Chandler NP. A comparison of phosphor-plate digital images with conventional radiographs for the perceived clarity of fine endodontic files and periapical lesions. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2002; 93(3):321-7.

18. Wenzel A, Kirkevang LL. Students' attitudes to digital radiography and measurement accuracy of two digital systems in connection with root canal treatment. Eur J Dent Educ. 2004; 8(4):167-71.

19. Wenzel A, Moystad A. Work flow with digital intraoral radiography: a systematic review. Acta Odontol Scand. 2010; 68(2):106-14.

20. Berkhout WE, Sanderink GC, Van der Stelt PF. Does digital radiography increase the number of intraoral radiographs? A questionnaire study of Dutch dental practices. Dentomaxillofac Radiol. 2003; 32(2):124-7.

21. White SC, Yoon DC. Comparative performance of digital and conventional images for detecting proximal surface caries. Dentomaxillofac Radiol. 1997; 26(1):32-8.

22. Haak R, Wicht MJ, Noack MJ. Conventional, digital and contrast-enhanced bitewing radiographs in the decision to restore approximal carious lesions. Caries Res. 2001; 35(3):193-9.

23. Haak R, Wicht MJ, Hellmich M, Noack MJ. Detection of marginal defects of composite restorations with conventional and digital radiographs. Eur J Oral Sci. 2002; 110(4):282-6.

24. Morner-Svalling AC, Tronje G, Andersson LG, Welander U. Comparison of the diagnostic potential of direct digital and conventional intraoral radiography in the evaluation of peri-implant conditions. Clin Oral Implants Res. 2003; 14(6):714-9.

25. Woolhiser GA, Brand JW, Hoen MM, Geist JR, Pikula AA, Pink FE. Accuracy of film-based, digital, and enhanced digital images for endodontic length determination. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2005; 99(4):499-504.

26. Mohtavipour ST, Dalili Z, Azar NG. Direct digital radiography versus conventional radiography for estimation of canal length in curved canals. Imaging Sci Dent. 2011; 41(1):7-10.

27. Sharkey S, Kelly A, Houston F, O'Sullivan M, Quinn F, O'Connell B. A radiographic analysis of implant component misfit. Int J Oral Maxillofac Implants. 2011; 26(4):807-15.

28. Tofangchiha M, Bakhshi M, Fakhar HB, Panjnoush M. Conventional and digital radiography in vertical root fracture diagnosis: a comparison study. Dent Traumatol. 2011; 27(2):143-6.

29. Nair MK, Nair UP. An in-vitro evaluation of Kodak Insight and Ektaspeed Plus film with a CMOS detector for natural proximal caries: ROC analysis. Caries Res. 2001; 35(5):354-9.

30. van der Stelt PF. Filmless imaging: the uses of digital radiography in dental practice. J Am Dent Assoc. 2005; 136(10):1379-87.

31. Wenzel A, Borg E, Hintze H, Grondahl HG. Accuracy of caries diagnosis in digital images from charge-coupled device and storage phosphor systems: an in vitro study. Dentomaxillofac Radiol. 1995; 24(4):250-4.

32. Tsuchida R, Araki K, Endo A, Funahashi I, Okano T. Physical properties and ease of operation of a wireless intraoral x-ray sensor. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2005; 100(5):603-8.

33. Matzen LH, Christensen J, Wenzel A. Patient discomfort and retakes in periapical examination of mandibular third molars using digital receptors and film. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009; 107(4):566-72.

34. Wenzel A, Frandsen E, Hintze H. Patient discomfort and cross-infection control in bitewing examination with a storage phosphor plate and a CCD-based sensor. J Dent. 1999; 27(3):243-6.

35. Goncalves A, Wiezel VG, Goncalves M, Hebling J, Sannomiya EK. Patient comfort in periapical examination using digital receptors. Dentomaxillofac Radiol. 2009; 38(7):484-8.

36. Farman AG, Farman TT. A comparison of 18 different x-ray detectors currently used in dentistry. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2005; 99(4):485-9.

37. Wenzel A, Haiter-Neto F, Gotfredsen E. Influence of spatial resolution and bit depth on detection of small caries lesions with digital receptors. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007; 103(3):418-22.

38. Brullmann DD, Kempkes B, d'Hoedt B, Schulze R. Contrast curves of five different intraoral X-ray sensors: a technical note. Oral Surg Oral Med Oral Pathol Oral Radiol. 2013; 115(6):e55-61.

39. de Oliveira ML, Pinto GC, Ambrosano GM, Tosoni GM. Effect of combined digital imaging parameters on endodontic file measurements. J Endod. 2012; 38(10):1404-7.

40. Li G, Berkhout WE, Sanderink GC, Martins M, van der Stelt PF. Detection of in vitro proximal caries in storage phosphor plate radiographs scanned with different resolutions. Dentomaxillofac Radiol. 2008; 37(6):325-9.

41. Wenzel A. Computer-aided image manipulation of intraoral radiographs to enhance diagnosis in dental practice: a review. Int Dent J. 1993; 43(2):99-108.

42. Wenzel A, Hintze H. Perception of image quality in direct digital radiography after application of various image treatment filters for detectability of dental disease. Dentomaxillofac Radiol. 1993; 22(3):131-4.

43. Analoui M. Radiographic image enhancement. Part I: spatial domain techniques. Dentomaxillofac Radiol. 2001; 30(1):1-9.

44. Analoui M. Radiographic digital image enhancement. Part II: transform domain techniques. Dentomaxillofac Radiol. 2001; 30(2):65-77.

45. Gotfredsen E, Wenzel A, Grondahl HG. Observers' use of image enhancement in assessing caries in radiographs taken by four intra-oral digital systems. Dentomaxillofac Radiol. 1996; 25(1):34-8.

46. Tyndall DA, Ludlow JB, Platin E, Nair M. A comparison of Kodak Ektaspeed Plus film and the Siemens Sidexis digital imaging system for caries detection using receiver operating characteristic analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1998; 85(1):113-8.

47. Wenzel A, Haiter-Neto F, Gotfredsen E. Risk factors for a false positive test outcome in diagnosis of caries in approximal surfaces: impact of radiographic modality and observer characteristics. Caries Res. 2007; 41(3):170-6.

48. Yalcinkaya S, Kunzel A, Willers R, Thoms M, Becker J. Subjective image quality of digitally filtered radiographs acquired by the Durr Vistascan system compared with conventional radiographs. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2006; 101(5):643-51.

49. Haiter-Neto F, Casanova MS, Frydenberg M, Wenzel A. Task-specific enhancement filters in storage phosphor images from the Vistascan system for detection of proximal caries lesions of known size. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2009; 107(1):116-21.

50. Moystad A, Svanaes DB, Risnes S, Larheim TA, Grondahl HG. Detection of approximal caries with a storage phosphor system. A comparison of enhanced digital images with dental X-ray film. Dentomaxillofac Radiol. 1996; 25(4):202-6.

51. Svanaes DB, Moystad A, Larheim TA. Approximal caries depth assessment with storage phosphor versus film radiography. Evaluation of the caries-specific Oslo enhancement procedure. Caries Res. 2000; 34(6):448-53.

52. Kal BI, Baksi BG, Dundar N, Sen BH. Effect of various digital processing algorithms on the measurement accuracy of endodontic file length. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007; 103(2):280-4.

53. Vandenberghe B, Corpas L, Bosmans H, Yang J, Jacobs R. A comprehensive in vitro study of image accuracy and quality for periodontal diagnosis. Part 1: the influence of X-ray generator on periodontal measurements using conventional and digital receptors. Clin Oral Investig. 2011; 15(4):537-49.

54. Eickholz P, Riess T, Lenhard M, Hassfeld S, Staehle HJ. Digital radiography of interproximal bone loss; validity of different filters. J Clin Periodontol. 1999; 26(5):294-300.

55. Hadley DL, Replogle KJ, Kirkam JC, Best AM. A comparison of five radiographic systems to D-speed film in the detection of artificial bone lesions. J Endod. 2008; 34(9):1111-4.

56. Brettle D, Carmichael F. The impact of digital image processing artefacts mimicking pathological features associated with restorations. Br Dent J. 2011; 211(4):167-70.

57. Schweitzer DM, Berg RW. A digital radiographic artifact: A clinical report. J Prosthet Dent. 2010; 103(6):326-9.

58. Oestmann JW, Prokop M, Schaefer CM, Galanski M. Hardware and software artifacts in storage phosphor radiography. Radiographics. 1991; 11(5):795-805.

59. Willis CE, Thompson SK, J. S. Artifacts and misadventures in digital radiography. Applied Radiology. 2004; 11-20.

60. Chasen MH. Practical applications of Mach band theory in thoracic analysis. Radiology. 2001; 219(3):596-610.

61. Nielsen CJ. Effect of scenario and experience on interpretation of mach bands. J Endod. 2001; 27(11):687-91.

62. Rose SC, Moore EE. Angiographic artifacts that simulate arterial pathology in acute trauma. Am J Emerg Med. 1990; 8(2):109-17.

63. Drost WT, Reese DJ, Hornof WJ. Digital radiography artifacts. Vet Radiol Ultrasound. 2008; 49(1 Suppl 1):S48-56.

64. Solomon SL, Jost RG, Glazer HS, Sagel SS, Anderson DJ, Molina PL. Artifacts in computed radiography. AJR Am J Roentgenol. 1991; 157(1):181-5.

65. Shetty CM, Barthur A, Kambadakone A, Narayanan N, Kv R. Computed radiography image artifacts revisited. AJR Am J Roentgenol. 2011; 196(1):W37-47.

66. Farman AG, Scarfe WC. Development of imaging selection criteria and procedures should precede cephalometric assessment with cone-beam computed tomography. Am J Orthod Dentofacial Orthop. 2006; 130(2):257-65.

67. Farman AG. ALARA still applies. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2005; 100(4):395-7.

68. Scarfe WC, Farman AG, Sukovic P. Clinical applications of cone-beam computed tomography in dental practice. J Can Dent Assoc. 2006; 72(1):75-80.

69. Ludlow JB, Davies-Ludlow LE, Brooks SL, Howerton WB. Dosimetry of 3 CBCT devices for oral and maxillofacial radiology: CB Mercuray, NewTom 3G and i-CAT. Dentomaxillofac Radiol. 2006; 35(4):219-26.

70. Ludlow JB, Ivanovic M. Comparative dosimetry of dental CBCT devices and 64-slice CT for oral and maxillofacial radiology. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008; 106(1):106-14.

71. Pauwels R, Beinsberger J, Collaert B, Theodorakou C, Rogers J, Walker A, et al. Effective dose range for dental cone beam computed tomography scanners. Eur J Radiol. 2012; 81(2):267-71.

72. Qu XM, Li G, Ludlow JB, Zhang ZY, Ma XC. Effective radiation dose of ProMax 3D cone-beam computerized tomography scanner with different dental protocols. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2010; 110(6):770-6.

73. De Vos W, Casselman J, Swennen GR. Cone-beam computerized tomography (CBCT) imaging of the oral and maxillofacial region: a systematic review of the literature. Int J Oral Maxillofac Surg. 2009; 38(6):609-25.

74. Liedke GS, da Silveira HE, da Silveira HL, Dutra V, de Figueiredo JA. Influence of voxel size in the diagnostic ability of cone beam tomography to evaluate simulated external root resorption. J Endod. 2009; 35(2):233-5.

75. Estevez R, Aranguren J, Escorial A, de Gregorio C, De La Torre F, Vera J, et al. Invasive cervical resorption Class III in a maxillary central incisor: diagnosis and follow-up by means of cone-beam computed tomography. J Endod. 2010; 36(12):2012-4.

76. da Silveira PF, Vizzotto MB, Liedke GS, da Silveira HL, Montagner F, da Silveira HE. Detection of vertical root fractures by conventional radiographic examination and cone beam computed tomography - an in vitro analysis. Dent Traumatol. 2013; 29(1):41-6.

77. Kottoor J, Velmurugan N, Surendran S. Endodontic management of a maxillary first molar with eight root canal systems evaluated using cone-beam computed tomography scanning: a case report. J Endod. 2011; 37(5):715-9.

78. Shemesh H, Cristescu RC, Wesselink PR, Wu MK. The use of cone-beam computed tomography and digital periapical radiographs to diagnose root perforations. J Endod. 2011; 37(4):513-6.

79. Vizzotto MB, Silveira PF, Arus NA, Montagner F, Gomes BP, da Silveira HE. CBCT for the assessment of second mesiobuccal (MB2) canals in maxillary molar teeth: effect of voxel size and presence of root filling. Int Endod J. 2013; 46(9):870-6.

80. Radiation protection n° 172: Cone Beam CT for dental and maxillofacial radiology, (2012).

81. ICRP. Recomendations of the International Comissiono n Radiological Protection. ICRP Publication 60. Ann ICRP. 1991; 21(

82. Akdeniz BG, Grondahl HG, Magnusson B. Accuracy of proximal caries depth measurements: comparison between limited cone beam computed tomography, storage phosphor and film radiography. Caries Res. 2006; 40(3):202-7.

83. Tsuchida R, Araki K, Okano T. Evaluation of a limited cone-beam volumetric imaging system: comparison with film radiography in detecting incipient proximal caries. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007; 104(3):412-6.

84. Kalathingal SM, Mol A, Tyndall DA, Caplan DJ. In vitro assessment of cone beam local computed tomography for proximal caries detection. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2007; 104(5):699-704.

85. Haiter-Neto F, Wenzel A, Gotfredsen E. Diagnostic accuracy of cone beam computed tomography scans compared with intraoral image modalities for detection of caries lesions. Dentomaxillofac Radiol. 2008; 37(1):18-22.

86. Qu X, Li G, Zhang Z, Ma X. Detection accuracy of in vitro approximal caries by cone beam computed tomography images. Eur J Radiol. 2011; 79(2):e24-7.

87. Charuakkra A, Prapayasatok S, Janhom A, Pongsiriwet S, Verochana K, Mahasantipiya P. Diagnostic performance of cone-beam computed tomography on detection of mechanically-created artificial secondary caries. Imaging Sci Dent. 2011; 41(4):143-50.

88. Tyndall DA, Price JB, Tetradis S, Ganz SD, Hildebolt C, Scarfe WC. Position statement of the American Academy of Oral and Maxillofacial Radiology on selection

criteria for the use of radiology in dental implantology with emphasis on cone beam computed tomography. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012; 113(6):817-26.

89. Benic GI, Sancho-Puchades M, Jung RE, Deyhle H, Hammerle CH. In vitro assessment of artifacts induced by titanium dental implants in cone beam computed tomography. Clin Oral Implants Res. 2013; 24(4):378-83.

90. Sanders MA, Hoyjberg C, Chu CB, Leggitt VL, Kim JS. Common orthodontic appliances cause artifacts that degrade the diagnostic quality of CBCT images. J Calif Dent Assoc. 2007; 35(12):850-7.

91. Schulze R, Heil U, Gross D, Bruellmann DD, Dranischnikow E, Schwanecke U, et al. Artefacts in CBCT: a review. Dentomaxillofac Radiol. 2011; 40(5):265-73.

92. Boas FE, Fleischmann D. Evaluation of two iterative techniques for reducing metal artifacts in computed tomography. Radiology. 2011; 259(3):894-902.

93. Boas FE, Fleischmann D. CT artifacts: Causes and reduction techniques. Imaging Med. 2012; 4(2):229-40.

94. Pauwels R, Beinsberger J, Stamatakis H, Tsiklakis K, Walker A, Bosmans H, et al. Comparison of spatial and contrast resolution for cone-beam computed tomography scanners. Oral Surg Oral Med Oral Pathol Oral Radiol. 2012; 114(1):127-35.

95. Kataoka ML, Hochman MG, Rodriguez EK, Lin PJ, Kubo S, Raptopolous VD. A review of factors that affect artifact from metallic hardware on multi-row detector computed tomography. Curr Probl Diagn Radiol. 2010; 39(4):125-36.

96. Draenert FG, Coppenrath E, Herzog P, Muller S, Mueller-Lisse UG. Beam hardening artefacts occur in dental implant scans with the NewTom cone beam CT but not with the dental 4-row multidetector CT. Dentomaxillofac Radiol. 2007; 36(4):198-203.

97. Chindasombatjaroen J, Kakimoto N, Murakami S, Maeda Y, Furukawa S. Quantitative analysis of metallic artifacts caused by dental metals: comparison of cone-beam and multi-detector row CT scanners. Oral Radiol. 2011; 27(114-20.

98. Esmaeili F, Johari M, Haddadi P, Vatankhah M. Beam Hardening Artifacts: Comparison between Two Cone Beam Computed Tomography Scanners. J Dent Res Dent Clin Dent Prospects. 2012; 6(2):49-53.

99. De Man B, Nuyts J, Dupont P, Marchal G, P. S. Metal Streak Artifacts in X-ray Computed Tomography: A Simulation Study. IEEE TRANSACTIONS ON NUCLEAR SCIENCE. 1999; 46(3):691-6.

ANEXO A – APROVAÇÃO NA COMISSÃO DE PESQUISA

UFRGS

- Linhas de Pesquisa
- Projetos de Pesquisa
- Áreas de Atuação
- Bolsas de Pesquisa
- Programa de Iniciação Científica Voluntário
- Programa de Fomento à Pesquisa(auxílio)
- Pós-doutorado

Sistema Pesquisa - Pesquisador: Heloisa Emilia Dias Da Silveira

Dados Gerais:

Projeto Nº:	23647	**Título:**	INFLUENCIA DA PRESENCA DE MATERIAIS METALICOS NA CAPACIDADE DIAGNOSTICA DE DIFERENTES METODOS POR IMAGEM – RADIOGRAFIA CONVENCIONAL, RADIOGRAFIA DIGITAL E TOMOGRAFIA COMPUTADORIZADA DE FEIXE CONICO –		
Área de conhecimento:	Radiologia Odontológica	**Início:**	01/11/2012	**Previsão de conclusão:**	30/06/2015
Situação:	Projeto em Andamento				
	Não possui projeto pai		**Não possui subprojetos**		
Origem:	Faculdade de Odontologia Programa de Pós-Graduação em Odontologia		**Projeto da linha de pesquisa:** DIAGNÓSTICO DE AFECÇÕES BUCO-FACIAIS		
Local de Realização:	não informado		**Projeto sem finalidade adicional** **Projeto não envolve aspecos éticos**		

Objetivo:

Analisar, in vitro, a interferência observada na imagem pela presença de materiais metálicos por meio da investigação da adaptação marginal de restaurações metálicas fundidas, coroas metálicas e componentes de implantes, empregando diferentes métodos – radiografia convencional, radiografia digital e tomografia computadorizada de feixe cônico – visando identificar o melhor protocolo frente a estas situações clínicas.

Palavras Chave:

ADAPTAÇÃO MARGINAL DENTÁRIA
DIAGNÓSTICO POR IMAGEM
RADIOGRAFIA DIGITAL
TOMOGRAFIA COMPUTADORIZADA DE FEIXE CÔNICO

Equipe UFRGS:

Nome: HELOISA EMILIA DIAS DA SILVEIRA
Coordenador - Início: 01/11/2012 Previsão de término: 30/06/2015

Nome: GABRIELA SALATINO LIEDKE
Outra: Aluno de Doutorado - Início: 01/11/2012 Previsão de término: 30/06/2015

Avaliações:

Comissão de Pesquisa de Odontologia - **Aprovado** em 05/08/2012 Clique aqui para visualizar o parecer

Anexos:

Projeto Completo	**Data de Envio:** 23/07/2012
Concordância de Instituição	**Data de Envio:** 23/07/2012
Concordância de Instituição	**Data de Envio:** 23/07/2012
Concordância de Instituição	**Data de Envio:** 23/07/2012
Termo de Consentimento Livre e Esclarecido	**Data de Envio:** 23/07/2012
Documento de Aprovação	**Data de Envio:** 23/07/2012
Formulário de Encaminhamento do Protocolo de Pesquisa com Animais	**Data de Envio:** 24/07/2012
Termo de Consentimento Livre e Esclarecido	**Data de Envio:** 21/11/2012

ANEXO B – APROVAÇÃO NO COMITÊ DE ÉTICA

Dados do Projeto de Pesquisa

Título da Pesquisa: INFLUENCIA DA PRESENCA DE MATERIAIS METALICOS NA CAPACIDADE DIAGNOSTICA DE DIFERENTES METODOS POR IMAGEM - RADIOGRAFIA CONVENCIONAL, RADIOGRAFIA DIGITAL E TOMOGRAFIA COMPUTADORIZADA DE FEIXE CÔNICO - ESTUDO IN VITRO

Pesquisador: Heloisa Emilia Dias da Silveira

Área Temática:

Versão: 3

CAAE: 06588312.9.0000.5347

Submetido em: 28/11/2012

Instituição Proponente: Universidade Federal do Rio Grande do Sul

Situação: Aprovado

Localização atual do Projeto: Pesquisador Responsável

Patrocinador Principal: Financiamento Próprio

ANEXO C – TERMOS DE DOAÇÃO DOS DENTES

TERMO DE DOAÇÃO DE DENTES HUMANOS – CIRURGIÃO-DENTISTA

O estabelecimento de novos protocolos para realização de exames radiográficos e/ou tomográficos que venham a melhorar o diagnóstico das complicações clínicas deve ser realizado mediante testes controlados em laboratório. Para tanto, é imprescindível a utilização de dentes humanos extraídos que simulem da melhor maneira a realidade clínica.

Os dentes doados serão utilizados para simulação de condições clínicas e posterior obtenção de imagens radiográficas e/ou tomográficas. O projeto de pesquisa foi previamente aprovado pela Comissão de Pesquisa da Faculdade de Odontologia e, a seguir, pelo Comitê de Ética em Pesquisa da UFRGS.

É garantido o anonimato dos doadores na divulgação dos resultados da pesquisa. Qualquer dúvida ou informação poderá ser obtida com os pesquisadores através do telefone (51) 3308.5199 ou com o Comitê de Ética da UFRGS pelo telefone (51) 3308-3629. Com o fim da presente pesquisa, os dentes poderão ser encaminhados ao Banco de Dentes da UFRGS ou utilizados em outra pesquisa pelo mesmo grupo.

Eu,____, inscrito no CRO _________, com consultório situado na ____, bairro __________________, cidade ___________, UF _____, CEP ___________, dôo _________ dentes para a pesquisa intitulada *“Influência da presença de materiais metálicos na capacidade diagnóstica de diferentes métodos por imagem – radiografia convencional, radiografia digital e tomografia computadorizada de feixe cônico – investigação in vitro”* sob responsabilidade dos pesquisadores *Gabriela Liedke e Heloisa Silveira*, declarando que o(s) dente(s) foi(foram) extraído(s) por indicação terapêutica, cujos históricos fazem parte dos prontuários dos pacientes de quem se originam, arquivados sob minha responsabilidade e cuja doação foi consentida por cada paciente.

____
Assinatura do cirurgião-dentista

Porto Alegre, ____ de _____________ de 20___.

TERMO DE DOAÇÃO DE DENTES HUMANOS - PACIENTES

O estabelecimento de novos protocolos para realização de exames radiográficos e/ou tomográficos que venham a melhorar o diagnóstico das mais diversas situações clínicas deve ser realizado mediante testes controlados em laboratório. Para tanto, é imprescindível a utilização de dentes humanos extraídos que simulem da melhor maneira a realidade clínica. Dessa forma, é importante a doação dos dentes extraídos para a realização de pesquisas.

Os dentes doados serão utilizados em pesquisas na área da radiologia para simulação de condições clínicas e posterior obtenção de imagens radiográficas e/ou tomográficas. É garantido o anonimato dos doadores na divulgação dos resultados da pesquisa. O projeto de pesquisa deverá ser previamente aprovado pela Comissão de Pesquisa da Faculdade de Odontologia e, a seguir, pelo Comitê de Ética em Pesquisa da UFRGS.

Eu, ____, RG____________, residente à ____, na cidade de _______________________ aceito doar o(s) dente(s) _______________ para pesquisa em Radiologia. Estou ciente de que o(s) dente(s) foi(foram) extraído(s) por indicação terapêutica para a melhoria da minha saúde, como documentado em meu prontuário. Fui informado que caso não aceitasse doar os dentes para a pesquisa, meu tratamento não seria prejudicado.

____

Assinatura do doador

Porto Alegre, ____ de _____________ de 20___.