Brazilian Dental Science

unesp
UNIVERSIDADE ESTADUAL PAULISTA
"JÚLIO DE MESQUITA FILHO"
Instituto de Ciência e Tecnologia
Campus de São José dos Campos

ORIGINAL ARTICLE DOI: https://doi.org/10.4322/bds.2025.e4770

# Influence of post-processing filters of tomographic images in the diagnosis of maladaptation of prosthetic crowns

Influência de filtros de pós-processamento de imagens tomográficas no diagnóstico de desadaptação de coroas protéticas

**Lúcia Andrea Contin MOREIRA**[1], **Luiz Miguel FERREIRA**[2], **Marcos Paulo MAIA-LIMA**[2], **Júlia Moreira DUTRA**[3], **Karina Lopes DEVITO**[4]

1 - Universidade Federal de Juiz de Fora, Faculdade de Odontologia, Departamento de Odontologia Restauradora, Programa de Pós-graduação em Odontologia. Juiz de Fora, MG, Brazil.
2 - Universidade Estadual de Campinas, Faculdade de Odontologia de Piracicaba, Departamento de Diagnóstico Oral, Programa de Pós-graduação em Estomatopatologia. Piracicaba, SP, Brazil.
3 - Universidade Federal de Juiz de Fora, Faculdade de Odontologia, Programa de Pós-graduação em Odontologia. Juiz de Fora, MG, Brazil.
4 - Universidade Federal de Juiz de Fora, Faculdade de Odontologia, Departamento de Clínica Odontológica. Juiz de Fora, MG, Brazil.

**How to cite:** Moreira LAC, Ferreira LM, Maia-Lima MP, Dutra JM, DEVITO KL. Influence of post-processing filters of tomographic images in the diagnosis of maladaptation of prosthetic crowns. Braz Dent Sci. 2025;28(2):e4770. https://doi.org/10.4322/bds.2025.e4770

## ABSTRACT

**Objective:** This study evaluated the impact of digital filters on enhancing cone beam computed tomography (CBCT) images for diagnosing marginal maladaptation of prosthetic crowns by specialists and academics. **Material and Methods:** CBCT was performed on 12 teeth restored with lithium disilicate ceramic crowns, duly adapted, and with maladaptations of 0.30 and 0.50 mm. The images were evaluated by three specialists and three students, regarding the presence of marginal gaps under three conditions of post-processing filters: "normal," "sharp," and "very sharp". Intra- and inter-examiner reproducibility were assessed using the Kappa index. Gap detection accuracy was determined using the area under the ROC curve, and the values for each group of examiners and tested filters were compared using analysis of variance and Tukey's post-hoc tests. **Results:** Intra- and inter-examiner agreement was considered moderate ($p \leq 0.05$), with Kappa indices ranging from 0.32 to 0.79 (mean = 0.52 / SD = ± 0.21) and 0.21 to 0.88 (mean = 0.45 / SD = ± 0.13), respectively. There was no significant difference between the filters ($p = 0.914$), but there was a notable difference between the examiners, with specialists outperforming academics ($p = 0.001$). **Conclusion:** Post-processing filters did not influence the diagnostic accuracy of marginal maladaptation in restorations based on lithium disilicate ceramics, as examined by experts and academics. However, there was a significant difference between the examiners, with better performance for the specialists.

## KEYWORDS

Ceramics; Cone-beam computed tomography; Dental marginal adaptation; Image enhancement; Lithium disilicate.

## RESUMO

**Objetivo:** Este estudo avaliou o impacto de filtros digitais no aprimoramento de imagens de tomografia computadorizada de feixe cônico (TCFC) para diagnóstico de má adaptação marginal de coroas protéticas por especialistas e acadêmicos. **Material e Métodos:** A TCFC foi realizada em 12 dentes restaurados com coroas de cerâmica de dissilicato de lítio, devidamente adaptadas, e com má adaptação de 0,30 e 0,50 mm. As imagens foram avaliadas por três especialistas e três estudantes, quanto à presença de falhas marginais sob três condições de filtros de pós-processamento: "normal", "nítido" e "muito nítido". A reprodutibilidade intra e interexaminador foi avaliada usando o índice Kappa. A precisão da detecção de falhas foi determinada usando a área sob a curva ROC, e os valores para cada grupo de examinadores e filtros testados foram comparados usando análise de variância e testes post-hoc de Tukey. **Resultados:** A concordância intra e interexaminadores foi considerada moderada ($p \leq 0,05$), com índices Kappa variando de 0,32 a 0,79 (média = 0,52 / DP = ± 0,21) e 0,21 a 0,88 (média = 0,45 / DP = ± 0,13), respectivamente. Não houve diferença significativa entre os filtros ($p = 0,914$), mas houve diferença notável entre os examinadores, com especialistas superando acadêmicos ($p = 0,001$). **Conclusão:** Os filtros de pós-processamento não influenciaram na acurácia diagnóstica da má adaptação marginal em restaurações de cerâmicas à base de dissilicato de lítio, conforme examinado por especialistas e acadêmicos. Entretanto, houve uma diferença significativa entre os examinadores, com melhor desempenho para os especialistas.

## PALAVRAS-CHAVE

Cerâmicas; Tomografia computadorizada de feixe cônico; Adaptação marginal dentária; Melhoramento de imagem; Dissilicato de lítio.

## INTRODUCTION

The longevity of a restorative treatment is strongly influenced by marginal adaptation, regardless of the type of material used [1]. The presence of gaps, also known as cracks, failures or marginal maladaptations, with great discrepancy, represent a relevant clinical challenge directly related to the loss of retention, the dissolution of cement, biofilm accumulation and the emergence of secondary carious lesions, due to the facilitation of microinfiltration by bacteria, resulting in the loss of restorative work [2].

The radiopacity of the restorative material and the technique used may have an impact on the radiographic evaluation of marginal maladaptations [3]. Thus, when imaging tests are requested to evaluate the marginal adaptation of indirect restorations, the limitations of two-dimensional radiographic examinations should be considered because of the overlapping of the structures [4]. For this reason, although it is not the preferred imaging test for the evaluation of dental restorations, cone-beam computed tomography (CBCT) has been widely used in dentistry owing to its high diagnostic potential, as well as the ability to evaluate three-dimensional images [5], without overlaps [6], in high spatial resolution [7] and enable image processing.

Its list of indications in dentistry is extensive, being traditionally used in the areas of implantology, endodontics, maxillofacial surgery and orthodontics [8]. Currently, the use of CBCT for other purposes has been investigated, which includes the identification of dental caries and marginal maladaptations of restorations [4,9,10]. Although it is not the purpose of using this test, CBCT images obtained for other causes may be useful for the evaluation of dental conditions [9].

However, the presence of high-density materials in rehabilitative components, along with specific parameters of the imaging device such as the quality of calibration and the size of the field of view (FOV), can significantly affect image quality. Inadequate or imprecise calibration can impair the scanner's ability to correctly interpret differences in tissue density, leading to distortions in the reconstructed image. This may enhance the formation of artifacts or obscure anatomical details, thereby increasing the risk of diagnostic errors [6,11].

When interpreting digital image exams, the dentist can use computational resources to enhance the quality of the image in relation to the original image through the application of digital enhancement filters [12]. The filters perform the function of increasing or decreasing the contrast of the adjacent voxels, which modifies the images, as it improves the low contrast resolution and reduces noise, or vice versa, depending on the filter used [13]. The software of the CBCT devices themselves allows the application of post-processing techniques, such as brightness adjustments, contrast and the use of digital filters, in order to improve the tomographic images and perhaps provide more accurate diagnoses [14].

Nevertheless, no studies in the literature have evaluated this tool with the aid of the diagnosis of indirect restoration gaps. In addition, studies evaluating these tools in CBCT exams are still limited, being mostly restricted to the field of Endodontics, due to their accuracy in detecting second mesiobuccal canals [15] and diagnosing of endodontic complications [16], such as root resorptions [17], bone loss [18], and fractures [12]. Therefore, there is a great demand for research evaluating the impact of these tools on image quality and diagnostic accuracy [14].

Given the relevance of the careful evaluation of the adaptation of indirect restorations and considering the probable interference of artifacts generated by the restorative material in the quality of tomographic images, causing possible interference in the diagnosis of marginal gaps, this study aimed to evaluate the influence of digital filters for post-processing of CBCT images in the diagnosis of marginal maladaptation of prosthetic crowns by specialists and academics. The hypotheses tested were: 1) The use of CBCT image enhancement filters improves the diagnosis of marginal maladaptation of prosthetic crowns; and 2) There is a significant difference in the accuracy of gap detection between students and experienced specialists.

## MATERIAL AND METHODS

The present study had an in vitro analytical experimental design and was conducted after approval by the Human Research Ethics Committee of the Federal University of Juiz de Fora (Juiz de Fora, Minas Gerais, Brazil) under opinion number 4.814.944.

### Sample preparation

A total of 14 healthy lower teeth (13 molars and one premolar) were obtained from the Human Teeth Bank of the School of Dentistry of the Federal University of Juiz de Fora, being that one molar and one premolar were used only to create proximal contact with the teeth of the sample. Molars with caries, fractures, restorations, and vestibulo-lingual and mesio-distal dimensions that were not similar or varied by more than 10% were excluded.

The 12 teeth of the sample were submitted to preparations for total crown by a single prosthodontist, who performed occlusal wear of 2 mm and axial wear of 1.2 mm. All preparations had expulsive walls and rounded angles to facilitate accommodation of the prosthetic piece.

Subsequently, the teeth were sent to a prosthesis laboratory, where they underwent digital scanning (Scanner 3Shape; Copenhagen, Denmark) and through the CAD-CAM system (Ceramill Motion 2, Amann Girrbach, Koblach, Austria) the crowns were planned virtually and organic polymer standards for CAD/CAM (Incadcam, Curitiba/PR) were milled. After the necessary laboratory steps, according to the manufacturer's recommendations, lithium disilicate ceramic crowns were fabricated using injection technology (IPS e.max Press LT A1; batch number Z04946; Ivoclar, Vivadent; Schaan, Liechtenstein). Disadaptations were intentionally made in the proximal mesial and distal faces; eight faces had marginal maladaptation of 300 $\mu$m (0.3 mm), eight had maladaptation of 500 $\mu$m (0.5 mm), and eight faces presented adequate marginal adaptation (Figure 1), whose distribution between the teeth can be seen in the Table I.

The gaps in the vestibular and lingual surfaces were not simulated, considering that the maladaptations in these regions are more easily identified in the clinical examination [4].

The crowns were not cemented to the teeth, but only positioned in place, as in previous studies [4,10,19], because the presence of cement could mask the simulated marginal maladaptations. Thus, for the accommodation of the crown, a settling force of 2 Kgf was standardized on the occlusal surface of the crown, perpendicular to the long axis of the tooth.

For the fixation of the teeth and simulation of the human tomographic bone density, an artificial edentulous mandible made of barium (Nacional Ossos, Jaú, SP, Brazil) was used, where alveoli were made to insert the study teeth.

The density of the gums and facial soft tissues was simulated with the aid of utility wax (Technew, Rio de Janeiro, Brazil), positioned on the vestibular and lingual surface of the mandible, with a thickness of 15 mm [20]. In addition, a structure produced in wax was positioned to simulate the tongue in the central region of the mandible [21].

**Table I -** Division of teeth according to the marginal maladaptations produced

| Tooth | Mesial Face | Distal Face |
|---|---|---|
| 1 | Adapted | Adapted |
| 2 | Gap 0.3 mm | Gap 0.3 mm |
| 3 | Gap 0.5 mm | Gap 0.5 mm |
| 4 | Adapted | Adapted |
| 5 | Gap 0.3 mm | Gap 0.3 mm |
| 6 | Gap 0.5 mm | Gap 0.5 mm |
| 7 | Gap 0.5 mm | Adapted |
| 8 | Adapted | Gap 0.3 mm |
| 9 | Gap 0.3 mm | Gap 0.5 mm |
| 10 | Gap 0.5 mm | Adapted |
| 11 | Adapted | Gap 0.3 mm |
| 12 | Gap 0.3 mm | Gap 0.5 mm |

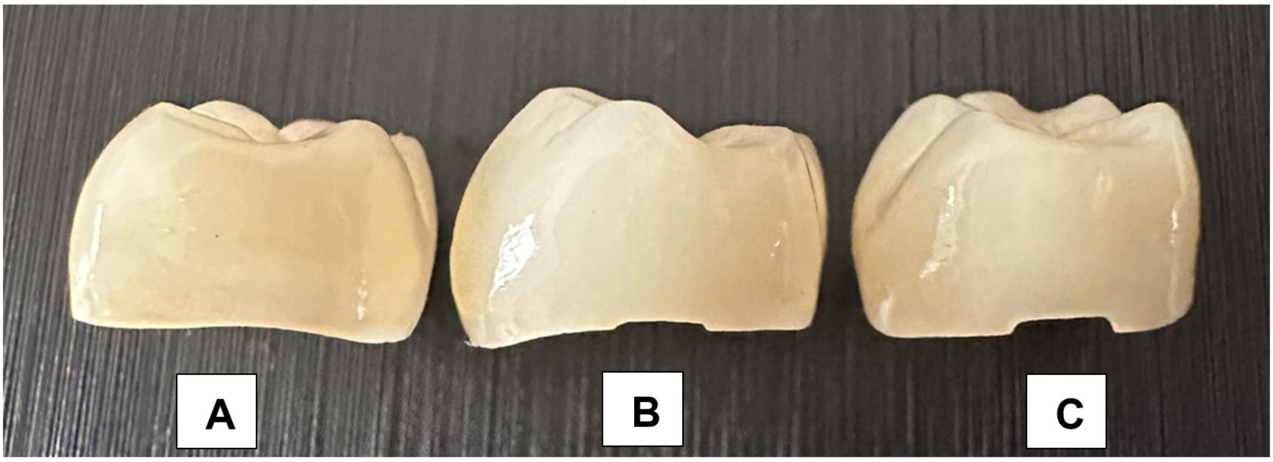


**Figure 1 -** Lithium disilicate crowns with integral margin (A), marginal maladaptation of 0.3 mm (B) and 0.5 mm (C).

The teeth and their respective crowns were inserted into the alveoli and fixed with the aid of useful wax. Each restored tooth was positioned between two healthy teeth, a premolar in the mesial position and a molar located in the distal position, to simulate the point of contact (Figure 2). The healthy teeth were always the same and did not have their positions changed, only the restored teeth were changed.

## Image acquisition and export

The correctly positioned restored teeth were subjected to CBCT examinations at the Dental Radiology Clinic of the School of Dentistry of the Federal University of Juiz de Fora using the I-Cat® Next Generation device (Imaging Sciences International, Hatfield, PA, USA), with the following acquisition protocol: 120 kV, 5 mA, and 360° of rotation, FOV of 4 x 16 cm, and voxel of 0.20 mm. The CT scans were then exported in DICOM (Digital Imaging and Communications in Medicine) format to a storage unit.

## Image preparation

The I-Cat® Vision software (Imaging Sciences International, Hatfield, PA, USA, version 1.8.1.10) was used to reconstruct the images. The restored tooth was aligned (its long axis was positioned perpendicular to the axial plane), and five sagittal images were generated in the vestibulo-lingual direction, with equidistant distances of 0.4 mm, for each proximal face, with the objective of covering the entire length of the gap, which was projected with a width of 2 mm. The protocol was performed using three digital filters to enhance CBCT images: “normal” filter (without filter application), “sharp” and “very sharp”, as can be seen in Figure 3.

**Figure 2 -** Phantom of clinical simulation of the jaw.

After the acquisition of the cuts, the images were exported individually from the software in TIFF format (Tag Image File Format) with a resolution of 96 dpi (dots per inch) without compression, so that there was no loss of resolution, totaling 360 images (12 teeth x 2 proximal faces x 5 cuts x 3 filters).

All images were standardized with a size of 4.5 cm high by 6 cm wide, evidencing the mid-coronary section of the teeth, resembling periapical radiography. Then, a slide show was created using Microsoft® PowerPoint® 2016 MSO software (Version 2305 Build 16.0.16501.20074), with five sequential cuts of each proximal face of each tooth and with a filter applied per slide on a black background, resulting in 72 templates (12 teeth x 2 proximal faces x 3 filters), which were randomized so that the evaluators did not identify the teeth. In addition, each slide contained an arrow indicating the vestibulo-lingual orientation of the

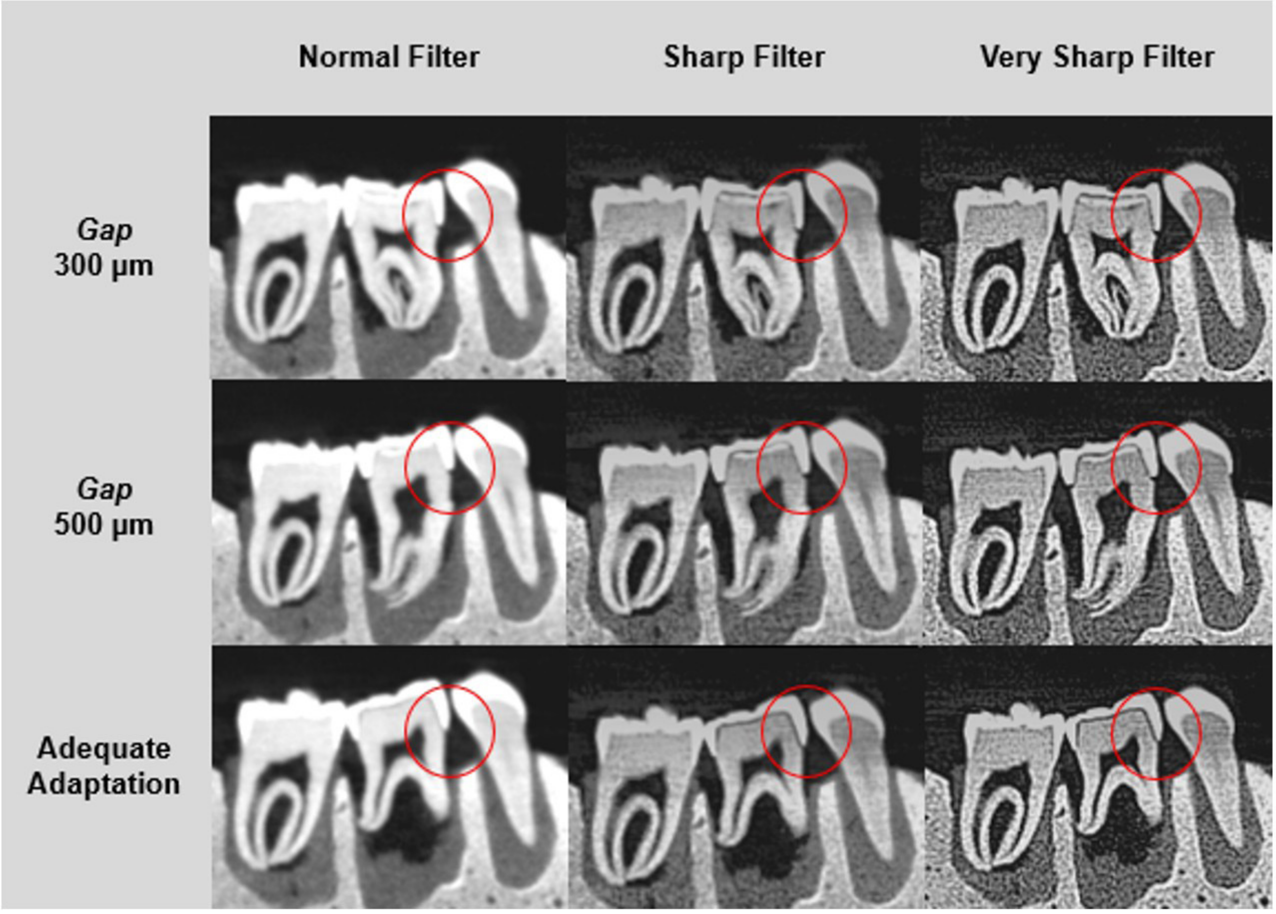


**Figure 3 -** Examples of CBCT images of teeth with adapted and maladapted prosthetic crowns subjected to post-processing filters.

sections, a numbering so that the evaluators could orient themselves in filling out the evaluation worksheet, and the indication of which proximal face (mesial or distal) should be analyzed.

## Image evaluation

Three final-year dental students and three specialists in restorative dentistry with more than five years of experience were selected to blindly evaluate the CBCT images (they were unaware of the applied filters and gap locations), using the same Samsung monitor (Seoul, Korea do Sul) 18.5 inches, LED, with a screen resolution of 1366 × 768 pixels and 32-bit color depth, in a quiet room with low lighting, to improve observation conditions. All images were coded and randomized to avoid identification, and the use of image manipulation tools, except for zoom, was not authorized.

Independently, examiners evaluated the proximal faces of each tooth in the presence of gaps in the restored teeth. They were given a spreadsheet where they assigned a rating scale of five scores: (I) gap definitely absent; (II) gap probably absent; (III) uncertainty about the absence or presence of a gap; and (IV) gap probably present; (V) gap definitely present.

To measure the reproducibility of the method, all images were evaluated at two different times under the same parameters, with an interval of one week between them.

## Statistical analysis

To evaluate the intra and inter-examiner agreements, the Kappa indices were calculated, considering for analysis the following interpretation: 0: no agreement; 0.01 to 0.20: weak agreement; 0.21 to 0.40: regular agreement; 0.41 to 0.60: moderate agreement; 0.61 to 0.80: strong agreement; 0.81 to 0.99: almost perfect agreement and 1: perfect agreement [22].

To evaluate the accuracy of the detection of marginal gaps in CBCT images modified by post-processing filters, the areas under the receiver operating characteristic (ROC) curves were obtained for each group of examiners (specialists and academics).

Kolmogorov-Smirnov and Levene tests were applied to evaluate the normality and homogeneity of the data, respectively. An analysis of variance, two-factor ANOVA, with Tukey's post-hoc, was used to compare the accuracy values (area under the ROC curve), considering the independent variables "examiner" and "filter".

The SPSS program (Statistical Package for the Social Sciences, version 21.0, Chicago, USA) was used to perform statistical tests, with a significance level of 5% ($p \leq 0.05$).

## RESULTS

The results of the concordances were all significant ($p \leq 0.05$), with Kappa indices ranging from 0.32 to 0.79 (mean = 0.52 / SD = ± 0.21) for the intra-examiner agreement, and from 0.21 to 0.88 (mean = 0.45 / SD = ± 0.13) for the inter-examiner agreement, being considered moderate concordances [22].

The areas under the ROC curves were obtained to evaluate the accuracy of the tested filters (Table II). No significant difference was observed between the filters ($p = 0.914$); however, there was a significant difference between the examiners, and the specialists had higher success rates than the students in the dentistry course ($p = 0.001$). Figure 4 shows the ROC curves of the two groups of examiners for the three filters tested.

## DISCUSSION

Although not every unsatisfactory restoration gives rise to an injury, the proper marginal adjustment of dental restorations and crowns is a way to prevent the onset of periodontal diseases and recurrent caries lesions. Thus, the diagnosis of marginal maladaptations that exceed acceptable clinical limits is important for maintaining the health of the teeth and surrounding tissues, thereby ensuring clinical success [3,19,23,24].

The margins of a restoration or crown can be evaluated using clinical methods, such as visual inspection and tactile exploration (with dental floss or an explorer), in addition to imaging tests, as well as imaging techniques, such as radiography and CBCT. However, it is still a challenging diagnostic task, especially when the endings are in the interproximal or subgingival region of the teeth [4,25]. Therefore, imaging tests should be used to evaluate the interproximal surfaces more effectively [26]. A micro-CT device

**Table II -** Comparison between the accuracy values (area under the ROC curves) for the three filters tested in the CBCT diagnosis of marginal gaps was performed by two groups of examiners (specialists and academics of the dentistry course)

| Examiners | Filter<br>Normal<br>Mean (SD) | Sharp<br>Mean (SD) | Very Sharp<br>Mean (SD) |
|---|---|---|---|
| Specialists | 0.938 (0.03) | 0.950 (0.03) | 0.949 (0.03) |
| Academics | 0.828 (0.11) | 0.811 (0.13) | 0.781 (0.21) |

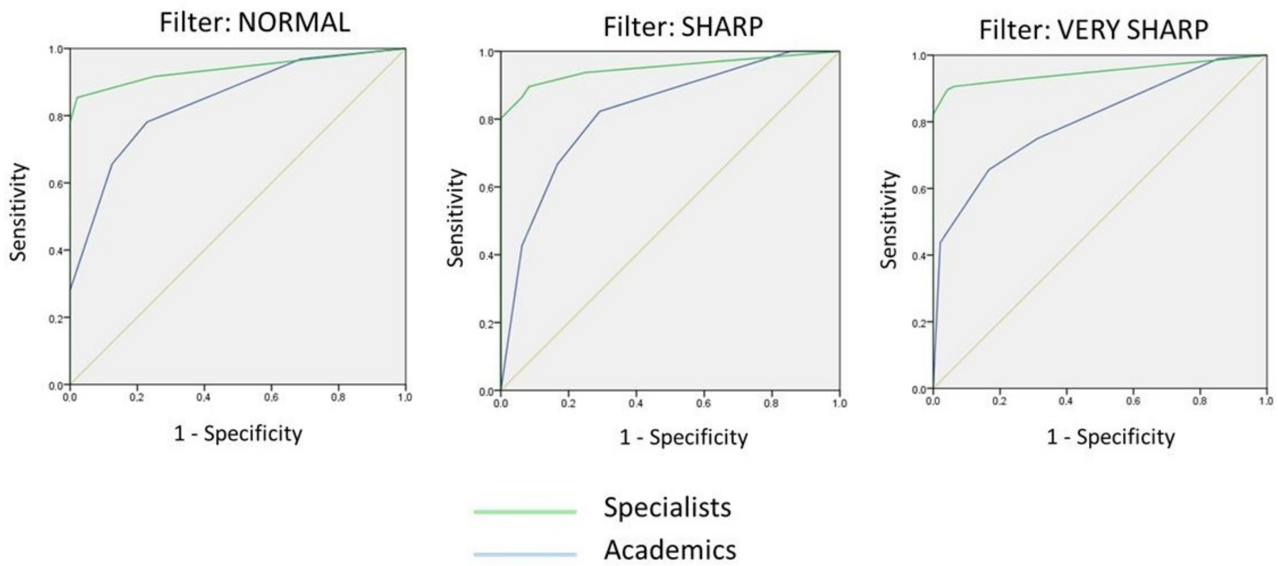


**Figure 4 -** ROC curves referring to the tomographic diagnosis of gaps for the three filters tested by specialists and academics from the dentistry course.

was used to measure the marginal discrepancy of restorations in the study by Mosharraf et al. [19].

When it comes to restorations performed using lithium dissilicate ($Li_2Si_2O_5$)-based ceramics, a material that has been the subject of many clinical and laboratory studies evaluating marginal adaptation [23,27,28], fracture resistance [28,29], biocompatibility [30] and patient satisfaction [27,28], these have acceptable radiopacity and did not affect the diagnostic capacity in the CBCT exam for the detection of proximal caries [31]. Furthermore, Aglarci et al. [32] pointed out that CBCT could be used to detect caries under fixed crowns after cementation, as a highly validated post-treatment diagnostic technique.

CBCT images can be manipulated using tools available in various software programs. Given the existing scientific gap regarding how these tools affect image quality and diagnostic accuracy [14], this study aimed to evaluate the influence of digital CBCT image enhancement filters on the diagnosis of marginal maladaptation in lithium disilicate-based ceramic restorations.

To increase or decrease specific characteristics of the image, digital filters use mathematical algorithms [17], with the purpose of visually improving and making the aspects of the original image more visible, generating more diagnostic information [33]. This function can allow the increase or decrease of the contrast of the adjacent voxels, which modifies the images, as it improves the density and contrast characteristics and reduces the noise, varying according to the filter used [13,14]. Thus, for the clinician to decide in which situations to use the filters, it is crucial to understand how these algorithms work and their specificities [34].

In this sense, the hypothesis of this study that there would be significant differences in the use of filters for the identification of marginal maladaptations was rejected ($p = 0.914$), corroborating other studies [12,15,16,35] that also did not find an improvement in accuracy during other diagnostic tasks when applying digital filters. In addition, no studies in the scientific literature have evaluated the influence of filters on the diagnosis of marginal maladaptation of prosthetic crowns, especially those of lithium disilicate ceramic. Studies that presented the same results as ours analyzed the use of filters for the diagnosis of endodontic complications, such as fractured files, deviated pins, perforations, external root resorptions [16], vertical root fractures [12,35] and detection of the second mesiobuccal canal [15].

Another variable analyzed in this study was the ability of the two groups of evaluators to diagnose marginal gaps. According to the results, the hypothesis that specialists would perform better than students was confirmed ($p < 0.01$). Unlike the other studies [17,36,37], ours was the only study that performed this comparison, and the others only selected specialists in dental radiology to evaluate CBCT examinations. The present study selected specialists in dentistry, that is, professionals who perform this type of clinical procedure in their daily lives. Only Sousa et al. [18] included in their research design a dental student to perform the evaluations of CBCT images together with a radiology specialist.

The inter-rater agreement was better than the intra-examiner agreement for the detection of maladaptation in indirect restorations. However, the means of the Kappa index were within an acceptable limit, according to Landis and Koch [22], and were classified as moderate concordances. This may indicate that each evaluator was more or less consistent in differentiating between the presence and absence of gaps. Similarly, Doriguêtto et al. [9] declared agreement ranging from regular to moderate when evaluating marginal gaps in teeth restored with pure ceramics and metal-ceramic crowns.

In line with Verner et al. [16], when comparing the results of the present study with those of other studies, some factors should be considered because of methodological differences. The main differences concerned the types of imaging protocols, structures evaluated (marginal gaps, pathological bone lesions, dental resorption, root fractures, or endodontic complications), types of samples (in vivo or vitro), and evaluation methodologies (evaluators, software, and filters).

In this logic, the most used tomograph in the investigations of this theme was the same equipment of this study: the I-Cat9 [14,16-18,34-36,38,39]. Another important factor in image acquisition protocols is FOV and voxel sizes [11]. According to Mouzinho-Machado et al. [15], a smaller voxel size (80 $\mu$m) increases diagnostic accuracy. However, like other studies [34-36,38], we used a single voxel size (0.2 mm). Regarding the exposure area, we used a wide FOV (4 x 16 cm), as in Costa et al. [38], simulating a patient who needs to scan the entire lower arch.

The evaluation methodologies of the studies are also heterogeneous, and the main software of choice for image analysis are OnDemand, XoranCat, and i-CAT Vision [12,36,37]. It is worth mentioning that the XoranCat program provides a greater number of filters when compared to OnDemand, for example. The researchers that applied the i-CAT Vision post-processing filters selected the “Normal”, “Sharp” and “Very Sharp” filters, as well as our study [12,18,39]. The “Very Sharp” filter obtained a better performance when compared to the other two, which justifies its use for clinical activities [39]. In our study, none of the three filters influenced the diagnosis of marginal gaps, and Martin e Silva et al. [12], found no significant difference in the accuracy of the diagnosis of vertical root fractures when the post-processing filters were varied.

Similar to other in vitro studies [15,39], this study has limitations regarding the clinical information, signs, symptoms, and intrinsic characteristics of the patient, such as changes in tissue thickness and density, which could help or hinder the process of diagnosing gaps. Another limitation was the impossibility of allowing the evaluators to freely manipulate the CBCT examinations since they could identify the filters and teeth used, implying bias. However, some studies have shown that the file format of digital radiographs does not influence the diagnosis of internal and external root resorption [40], vertical root fracture [41] and proximal caries lesions [42]. Thus, it is understood that the way this study was conducted did not have negative effects on the quality of the images or on the diagnostic accuracy, although there are no studies in the literature that evaluate the influence of the file format on CBCT images. Furthermore, although this format limitation could potentially influence the evaluation, it was intentionally controlled in this study and constitutes a necessary methodological restriction to meet the experimental design and proposed objectives.

Knowing that the quality of the CBCT image can be affected by the acquisition factors used: kilovoltage (kV), milliamperage (mA), voxel, and FOV size [6,11], this study had another limiting factor, since it restricted the use of only one tomograph with unique exposure settings, thus reducing the possibility of comparing the results obtained with those described in the literature, which used different CBCT equipment and varied exposure protocols. Studies that have used image enhancement filters from other software programs may also yield different results. Therefore, further investigations should be conducted for different diagnostic tasks by applying other digital filters or image enhancement algorithms in the post-processing phase of CT scans.

## CONCLUSION

In the exposure protocol evaluated, the application of post-processing filters to CBCT images did not affect the diagnostic accuracy for detecting marginal maladaptation in indirect lithium disilicate ceramic restorations. Therefore, the use of filters can be guided by the professional’s preference. It is worth noting, however, that a significant difference was observed between examiners, with specialists demonstrating superior performance.

## Author’s Contributions

LACM: Methodology, Investigation, Data Curation, Writing – Original Draft Preparation, Writing – Review & Editing. LMF: Methodology, Investigation, Data Curation, Writing – Original Draft Preparation, Writing – Review & Editing. MPML: Methodology, Investigation, Data Curation, Writing – Original Draft Preparation, Writing – Review & Editing. JMD: Contribution of the author: Methodology, Investigation, Data Curation, Writing – Original Draft Preparation, Writing – Review & Editing. KLD: Methodology, Investigation, Writing – Original Draft Preparation, Writing – Review & Editing.

## Conflict of Interest

No conflicts of interest declared concerning the publication of this article.

## Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or non-profit sectors.

## Regulatory Statement

This study protocol was reviewed and approved by the Human Research Ethics Committee of the Federal University of Juiz de Fora (Juiz de Fora, Minas Gerais, Brazil), approval number 4.814.944.

# REFERENCES


1. Ferrairo BM, Piras FF, Lima FF, Honório HM, Duarte MAH, Borges AFS, et al. Comparison of marginal adaptation and internal fit of monolithic lithium disilicate crowns produced by 4 different CAD/CAM systems. Clin Oral Investig. 2021;25(4):2029-36. http://doi.org/10.1007/s00784-020-03511-1. PMid:32783095.
2. Borba M, Miranda WG Jr, Cesar PF, Griggs JA, Bona AD. Evaluation of the adaptation of zirconia-based fixed partial dentures using micro-CT technology. Braz Oral Res. 2013;27(5):396-402. http://doi.org/10.1590/S1806-83242013000500003. PMid:24036977.
3. Mjör IA. Clinical diagnosis of recurrent caries. J Am Dent Assoc. 2005;136(10):1426-33. http://doi.org/10.14219/jada.archive.2005.0057. PMid:16255468.
4. Mauad LQ, Doriguêtto PVT, Almeida D, Fardim KAC, Machado AH, Devito KL. Quantitative assessment of artefacts and identification of gaps in prosthetic crowns: a comparative in vitro study between periapical radiography and CBCT images. Dentomaxillofac Radiol. 2021;50(3):20200134. http://doi.org/10.1259/dmfr.20200134. PMid:32941742.
5. Park HN, Min CK, Kim KA, Koh KJ. Optimization of exposure parameters and relationship between subjective and technical image quality in cone-beam computed tomography. Imaging Sci Dent. 2019;49(2):139-51. http://doi.org/10.5624/isd.2019.49.2.139. PMid:31281791.
6. Vedpathak PR, Gondivkar SM, Bhoosreddy AR, Shah KR, Verma GR, Mehrotra GP, et al. Cone beam computed tomography: an effective tool in detecting caries under fixed dental prostheses. J Clin Diagn Res. 2016;10(8):ZC10-3. http://doi.org/10.7860/JCDR/2016/18589.8228. PMid:27656548.
7. Long H, Zhou Y, Ye N, Liao L, Jian F, Wang Y, et al. Diagnostic accuracy of CBCT for tooth fractures: a meta-analysis. J Dent. 2014;42(3):240-8. http://doi.org/10.1016/j.jdent.2013.11.024. PMid:24321294.
8. Friedlander-Barenboim S, Hamed W, Zini A, Yarom N, Abramovitz I, Chweidan H, et al. Patterns of Cone-Beam Computed Tomography (CBCT) utilization by various dental specialties: a 4-year retrospective analysis from a dental and maxillofacial specialty center. Healthcare. 2021;9(8):1042. http://doi.org/10.3390/healthcare9081042. PMid:34442182.
9. Doriguêtto PVT, Almeida D, Lima CO, Lopes RT, Devito KL. Assessment of marginal gaps and image quality of crowns made of two different restorative materials: an in vitro study using CBCT images. J Dent Res Dent Clin Dent Prospect. 2022;16(4):243-50. http://doi.org/10.34172/joddd.2022.039. PMid:37560496.
10. Liedke GS, Spin-Neto R, Vizzotto MB, Silveira PF, Wenzel A, Silveira HE. Diagnostic accuracy of cone beam computed tomography sections with various thicknesses for detecting misfit between the tooth and restoration in metal-restored teeth. Oral Surg Oral Med Oral Pathol Oral Radiol. 2015;120(2):e131-7. http://doi.org/10.1016/j.oooo.2015.05.004. PMid:26166035.
11. Pauwels R, Araki K, Siewerdsen JH, Thongvigitmanee SS. Technical aspects of dental CBCT: state of the art. Dentomaxillofac Radiol. 2015;44(1):20140224. http://doi.org/10.1259/dmfr.20140224. PMid:25263643.
12. Martin e Silva D, Campos CN, Pires Carvalho AC, Devito KL. Diagnosis of mesiodistal vertical root fractures in teeth with metal posts: influence of applying filters in cone-beam computed tomography images at different resolutions. J Endod. 2018;44(3):470-4. http://doi.org/10.1016/j.joen.2017.08.030. PMid:29153985.
13. Sagawa M, Miyoseta Y, Hayakawa Y, Honda A. Comparison of two-and three-dimensional filtering methods to improve image quality in multiplanar reconstruction of cone-beam computed tomography. Oral Radiol. 2009;25(2):154-8. http://doi.org/10.1007/s11282-009-0026-9.
14. Verner FS, Visconti MAPG, Junqueira RB, Dias IM, Ferreira LA, Devito KL. Performance of cone-beam computed tomography filters for detection of temporomandibular joint osseous changes. Oral Radiol. 2015;31(2):90-6. http://doi.org/10.1007/s11282-014-0192-2.
15. Mouzinho-Machado S, Rosado LPL, Coelho-Silva F, Neves FS, Haiter-Neto F, de-Azevedo-Vaz SL. Influence of voxel size and filter application in detecting second mesiobuccal canals in cone-beam computed tomographic images. J Endod. 2021;47(9):1391-7. http://doi.org/10.1016/j.joen.2021.06.011. PMid:34166686.
16. Verner FS, D'Addazio PS, Campos CN, Devito KL, Almeida SM, Junqueira RB. Influence of Cone-Beam Computed Tomography filters on diagnosis of simulated endodontic complications. Int Endod J. 2017;50(11):1089-96. http://doi.org/10.1111/iej.12732. PMid:27977857.
17. Azevedo Vaz SL, Vasconcelos TV, Neves FS, Freitas DQ, Haiter-Neto F. Influence of cone-beam computed tomography enhancement filters on diagnosis of simulated external root resorption. J Endod. 2012;38(3):305-8. http://doi.org/10.1016/j.joen.2011.10.012. PMid:22341065.
18. Sousa ET, Pinheiro MA, Maciel PP, Sales MA. Influence of enhancement filters in apical bone loss measurement: A cone-beam computed tomography study. J Clin Exp Dent. 2017;9(4):e516-9. http://doi.org/10.4317/jced.53496. PMid:28469815.
19. Mosharraf R, Azizi A, Naziri B, Abolhasani M. The affects of cement space thickness and material type with application of micro-CT scanner on marginal discrepancy of restoration. Braz Dent Sci. 2021;24(1):1968.
20. Schropp L, Alyass NS, Wenzel A, Stavropoulos A. Validity of wax and acrylic as soft-tissue simulation materials used in in vitro radiographic studies. Dentomaxillofac Radiol. 2012;41(8):686-90. http://doi.org/10.1259/dmfr/33467269. PMid:22933536.
21. Farias Gomes A, Nejaim Y, Fontenele RC, Haiter-Neto F, Freitas DQ. Influence of the incorporation of a lead foil to intraoral digital receptors on the image quality and root fracture diagnosis. Dentomaxillofac Radiol. 2019;48(6):20180369. http://doi.org/10.1259/dmfr.20180369. PMid:30982341.
22. Landis JR, Koch GG. The measurement of observer agreement for categorical data. Biometrics. 1977;33(1):159-74. http://doi.org/10.2307/2529310. PMid:843571.
23. Abreu ECR, Ferreira VC, Olivieri KAN, Brandt WC. Marginal gap of zirconia and lithium disilicate frameworks produced by the CAD-CAM technique through a comparator microscope: in vitro analysis. Braz Dent Sci. 2024;27(1):e4154. http://doi.org/10.4322/bds.2024.e4154.
24. El-Banna HIM, Zamzam ML, El-Guindy JF, Idris AS. One-year clinical evaluation of IPS Empress CAD versus polished Celtra Duo ceramic Laminate veneers (randomized controlled clinical trial). Braz Dent Sci. 2021;24(3):i3.2595. http://doi.org/10.14295/bds.2021.v24i3.2595.
25. Liedke GS, Spin-Neto R, Silveira HE, Wenzel A. Radiographic diagnosis of dental restoration misfit: a systematic review. J Oral Rehabil. 2014;41(12):957-67. http://doi.org/10.1111/joor.12215. PMid:25142004.
26. 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. http://doi.org/10.1259/dmfr/87103878. PMid:18195250.
27. Khalil NSAA, Alansary H, Youssef EE. Shade match, marginal adaptation and patient satisfaction: polymer infiltrated ceramic versus lithium disilicate glass ceramic anterior laminate veneers

(randomized clinical trial). Braz Dent Sci. 2024;27(4):e4391. http://doi.org/10.4322/bds.2024.e4391.

28. El-Enein YA, Elguindy J, Zaki AA. One year clinical evaluation of e-max press crowns retained with fiber reinforced composite post versus e-max press endocrowns in anterior endodontically treated teeth a randomized clinical trial). Braz Dent Sci. 2021;24(2):i2.2413. http://doi.org/10.14295/bds.2021.v24i2.2413.

29. El-Etreby A, Metwally M, El-Nagar G. Effect of thermo-mechanical aging and repressing on fracture resistance of lithium disilicate crowns. Braz Dent Sci. 2021;24(3):i3.2545. http://doi.org/10.14295/bds.2021.v24i3.2545.

30. Odeh E, Alansary H, Naguib A, Taymour M. Evaluation of biocompatibility of veneered Bio HPP and veneered lithium disilicate crowns in anterior zone (randomized controlled clinical trial). Braz Dent Sci. 2021;24(4):i4.2700. http://doi.org/10.14295/bds.2021.v24i4.2700.

31. Abu El-Ela WH, Farid MM, Abou El-Fotouh M. The impact of different dental restorations on detection of proximal caries by cone beam computed tomography. Clin Oral Investig. 2022;26(3):2413-20. http://doi.org/10.1007/s00784-021-04207-w. PMid:34601634.

32. Aglarci OS, Bilgin MS, Erdem A, Ertas ET. Is it possible to diagnose caries under fixed partial dentures with cone beam computed tomography? Oral Surg Oral Med Oral Pathol Oral Radiol. 2015;119(5):579-83. http://doi.org/10.1016/j.oooo.2015.02.004. PMid:25864819.

33. Borg E, Gröndahl K, Persson LG, Gröndahl HG. Marginal bone level around implants assessed in digital and film radiographs: in vivo study in the dog. Clin Implant Dent Relat Res. 2000;2(1):10-7. http://doi.org/10.1111/j.1708-8208.2000.tb00102.x. PMid:11359270.

34. de-Azevedo-Vaz SL, Alencar PN, Rovaris K, Campos PS, Haiter-Neto F. Enhancement cone beam computed tomography filters improve in vitro periimplant dehiscence detection. Oral Surg Oral Med Oral Pathol Oral Radiol. 2013;116(5):633-9. http://doi.org/10.1016/j.oooo.2013.06.029. PMid:24018127.

35. Ferreira LM, Visconti MA, Nascimento HA, Dallemolle RR, Ambrosano GM, Freitas DQ. Influence of CBCT enhancement filters on diagnosis of vertical root fractures: a simulation study in endodontically treated teeth with and without intracanal posts. Dentomaxillofac Radiol. 2015;44(5):20140352. http://doi.org/10.1259/dmfr.20140352. PMid:25666446.

36. Nascimento MC, Nejaim Y, de Almeida SM, Bóscolo FN, Haiter-Neto F, Sobrinho LC, et al. Influence of cone beam CT enhancement filters on diagnosis ability of longitudinal root fractures. Dentomaxillofac Radiol. 2014;43(3):20130374. http://doi.org/10.1259/dmfr.20130374. PMid:24408819.

37. González AR, Tosoni GM, Freitas DQ, Oliveira ML. Influence of sharpening filters on the detection of root fractures using low-dose cone-beam computed tomography. Clin Oral Investig. 2022;26(7):4797-803. http://doi.org/10.1007/s00784-022-04444-7. PMid:35288809.

38. Costa ALF, Fardim KAC, Mantoani JM, Ricardo ALF, Jardini MAN, Orhan K, et al. In vitro quantitative evaluation of postprocessing filter for metal artifact reduction in cone beam computed tomography images of titanium and zirconium dioxide implants. BioMed Res Int. 2022;2022(1):1362473. http://doi.org/10.1155/2022/1362473. PMid:35295958.

39. Monteiro BM, Nobrega DS Fo, Lopes P M, Sales MA. Impact of image filters and observations parameters in CBCT for identification of mandibular osteolytic lesions. Int J Dent. 2012;2012:239306. http://doi.org/10.1155/2012/239306. PMid:22956955.

40. Miranda-Viana M, Madlum DV, Oliveira-Santos N, Gaêta-Araujo H, Haiter-Neto F, Oliveira ML. Influence of the image file format of digital periapical radiographs on the diagnosis of external and internal root resorptions. Clin Oral Investig. 2021;25(8):4941-8. http://doi.org/10.1007/s00784-021-03803-0. PMid:33495894.

41. Miranda-Viana M, Fontenele RC, Farias Gomes A, Nogueira-Reis F, Nejaim Y, Oliveira ML, et al. Digital file format does not influence the radiographic diagnosis of vertical root fracture. Oral Radiol. 2022;38(4):452-8. http://doi.org/10.1007/s11282-021-00573-z. PMid:34626307.

42. Madlum DV, Gaêta-Araujo H, Brasil DM, Lima CAS, Oliveira ML, Haiter-Neto F. Influence of the file format and transmission app on the radiographic diagnosis of caries lesions. Oral Surg Oral Med Oral Pathol Oral Radiol. 2021;132(4):448-55. http://doi.org/10.1016/j.oooo.2020.11.013. PMid:33386287.

**Karina Lopes Devito**
**(Corresponding address)**
Universidade Federal de Juiz de Fora, Faculdade de Odontologia, Departamento de Clínica Odontológica, Juiz de Fora, MG, Brazil.
**Email:** karina.devito@ufjf.br

Date submitted: 2025 Apr 13
Accept submission: 2025 May 07