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Novel 3-dimensional classification of cervical abrasion using CBCT: A comprehensive analysis

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A R T I C L E I N F O

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A B S T R A C T

Introduction: Tooth cervical abrasion (CA) is a prevalent non-carious cervical lesion that poses challenges for accurate diagnosis from periapical radiographs due to difficulties in assessing the lesion's extent, associated bone loss, and pulpal involvement. The presence of overlying bone structures on the palatal side when lesions are located on the buccal side, or vice versa, further complicates radiographic interpretation. So it is important to define the lesions in all three dimensions.

Objective: To provide a three-dimensional descriptive classification for cervical abrasion lesions using Cone Beam Computed Tomography (CBCT).

Method: A total of 50 patients with cervical abrasion were selected for the study. From these patients, teeth (n = 10) from each of the four different quadrants were chosen. A CBCT scan with a 6 × 6 cm field of view (FOV) was performed, and the DICOM files of the cervical lesions were transferred to 3-D imaging software. The CBCT images of the cervical abrasion lesions were assessed at the level of the deepest point of the lesion along the long axis of the tooth in both axial and sagittal planes. The height (A), buccolingual dimension (B), circumferential spread (C), and remaining dentine thickness (D) were evaluated and classified using new scoring criteria for each dimension. The reliability and reproducibility of the classification were assessed to ensure its clinical applicability.

Conclusion: CBCT can be utilized to classify tooth cervical abrasion in endodontics, enhancing diagnosis, analysis, and treatment outcomes. This three-dimensional view facilitates easier communication among clinicians, allows for tailored treatment approaches, and opens new avenues for research.

1. Introduction

The word "abrasion" originates from the Latin word "abrasum." Tooth cervical abrasion, characterized by the progressive loss of tooth structure near the cervical region, is a prevalent dental condition with significant clinical implications. The etiology of cervical abrasion is multifaceted.,[1,2] involving a complex interplay of mechanical, chemical,[3] and biological factors, such as faulty brushing patterns,[4] the use of hard dentifrices, betel nut chewing, chewing on pens and other objects as a part of nervous displacement behavior, pipe smoking, and different biting patterns including bruxism.[5] Understanding the morphological variations and patterns of cervical abrasion is crucial for diagnosis and treatment planning.[6].

Non-carious cervical lesions, including erosion, abrasion, and abfraction, share similar clinical appearances.[7] Understanding these lesions and determining the appropriate level of prevention depends on their morphological and etiological patterns. Erosions typically result from the action of acids, which can be a contributing factor.[8] Genuine abrasion lesions are solely caused by trauma, with the softening effect of acidic substances occurring later. Diagnosing, distinguishing, and differentiating the extent of these lesions is challenging without a distinct classification system.

The tooth's cervical abrasion clinical appearance and morphology in the buccolingual dimension has been classified with the treatment needs.[9] However, the three-dimensional aspect of these lesions has not been thoroughly studied, and a classification based on this aspect has not been established. A three-dimensional understanding of tooth cervical lesions is necessary to determine the appropriate mode of intervention. CBCT has been recommended as an imaging modality for resorptive lesions and can be utilized in evaluating tooth cervical

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abrasion lesions. Leaving the lesion undetected can lead to more severe cervical abrasion, bringing it closer to the pulp and potentially resulting in pulpal and apical involvement. Evidence from Patel et al.[10] on the classification of external cervical resorption can be simulated for the evaluation of cervical abrasion lesions. The treatment needs for cervical abrasion lesions have been studied and explained using the buccolingual dimension obtained from the Cervical Abrasion Index of Treatment Needs (CAITN) with the use of a customized CAITN probe.

CBCT can provide a three-dimensional evaluation of resorptive lesions. However, there is currently no three-dimensional classification for tooth cervical abrasion and the corresponding treatment needs. The existing classification of tooth cervical abrasion includes the buccolingual dimension using a customized CAITN probe.[11] The American Association of Endodontists and the American Academy of Oral and Maxillofacial Radiology recommend using CBCT for identifying lesions that are not diagnosable or are inconclusive with periapical radiographs.[12] Thus, there is a need for a three-dimensional classification to improve diagnosis and evaluation. The objective of this study is to provide a three-dimensional descriptive classification for cervical abrasion lesions using Cone Beam Computed Tomography (CBCT).

2. Method

The study involved selecting 50 patients with cervical abrasion (CA) lesions, from whom teeth (n = 10) from four different quadrants were evaluated. Three examiners (AJ, AG, IG) assessed the height, buccolingual dimension, circumferential spread, and remaining dentine thickness of the lesions. CBCT scans of the CA lesions, covering multiple teeth in the same arch, were taken using the NewTom Giano HR (Korea) with the following parameters: a 6 × 6 cm field of view (FOV), exposure time of 3.6 s, 90 kVp, 3.66 mA, and a voxel size of 0.3 mm. The DICOM (Digital Imaging and Communications in Medicine) files were transferred to the NNT 2D-3D imaging software (Korea) or any other 3D imaging software capable of measuring length and angle. The files were also analyzed using Carestream 3-D imaging software (Rochester, New York) to check for reproducibility and replicability.

The images were carefully analyzed at the level of the deepest point of the lesion and along the plane where the long axis of the tooth passes through it. The height of the lesion was measured from the cemento-enamel junction (CEJ) to the maximum vertical extent of the lesion using the length measurement tool in the sagittal slice along the plane of the long axis of the tooth. The horizontal extension of the lesion, or buccolingual dimension, was also measured using the length measurement tool in the sagittal slice. The circumferential spread of the lesion was measured at the deepest point of the lesion in the axial slice using the angle measurement tool, starting from the mesial endpoint, passing through the maximum trough or crest of the lesion, and extending to the distal endpoint. The remaining dentine thickness (RDT) was measured at the deepest point of the lesion in the axial slice by measuring the RDT horizontally using the length measurement tool. The inter-examiner reliability and reproducibility were verified based on the results obtained from the statistical analysis.

3. Report

3.1. Radiographic assessment

The radiographic assessment of non-carious cervical lesions (NCCLs) poses challenges in diagnosis and devising an effective treatment plan. Among NCCLs, cervical abrasions (CAs) often manifest as wedge-shaped or saucer-shaped radiolucencies around the cervical region[13] (Fig. 1A–D). The radiographic assessment of non-carious cervical lesions (NCCLs) poses challenges in diagnosis and devising an effective treatment plan. Among NCCLs, cervical abrasions (CAs) often manifest as wedge-shaped or saucer-shaped radiolucencies around the cervical region.[14] Furthermore, the presence of overlying bone structures in the palatal region when lesions are present on the buccal side, or vice versa, makes interpretation of radiographs even more challenging.

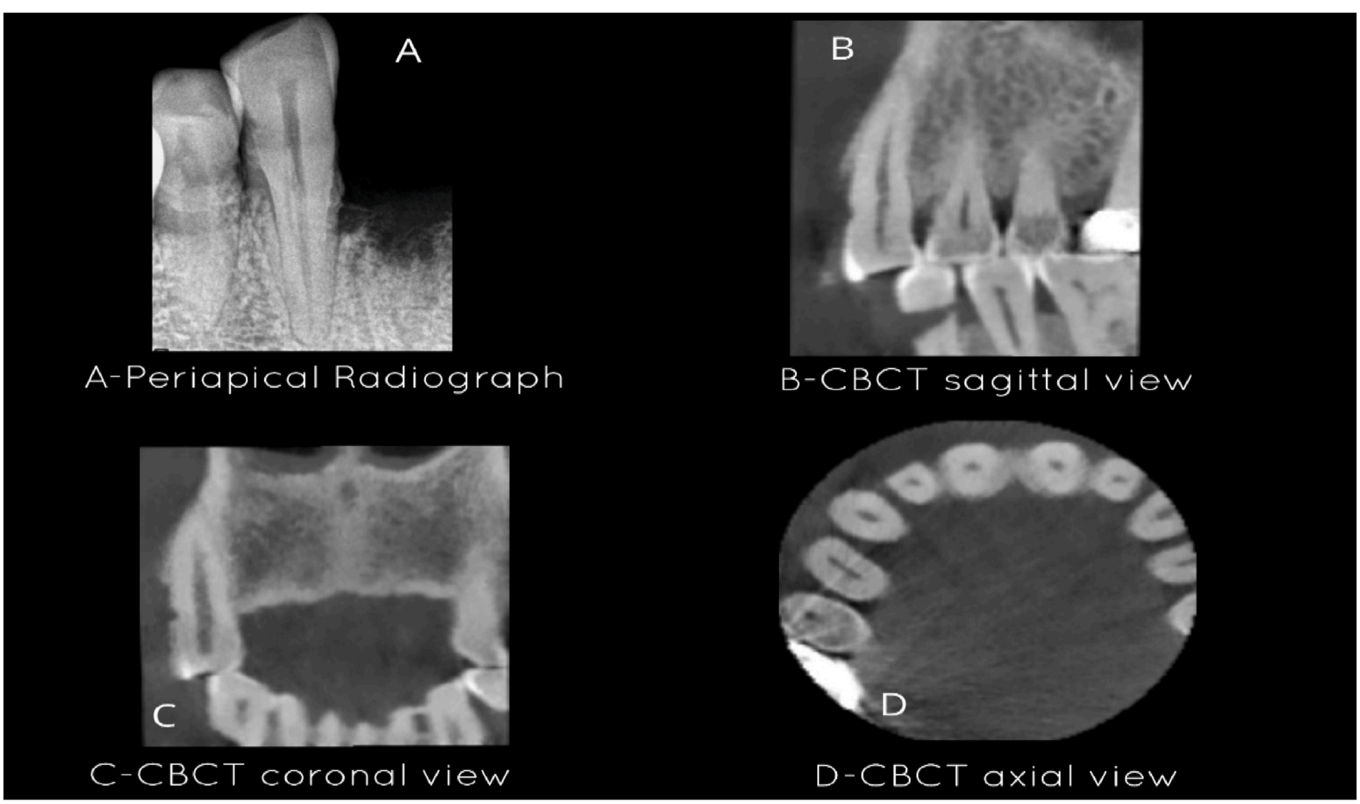

Fig. 1. (A–D) A-Periapical radiograph. **B**-CBCT sagittal view. **C**-CBCT coronal view **D**-CBCT axial view.

3.2. CBCT in CA diagnosis

CBCT has become increasingly important for the diagnosis and treatment planning of complex endodontic issues.[15] Although CBCT involves a higher radiation dose compared to periapical radiographs, this is balanced by its ability to provide better treatment planning and reduce the number of patient visits. Therefore, CBCT can be judiciously used in dentistry, particularly in endodontics.[16] The American Association of Endodontists, the American Academy of Oral and Maxillofacial Radiology, and the European Society of Endodontology recommend the use of CBCT when clinical and periapical radiographs are inconclusive, particularly in cases of cervical abrasion (CA).[16,17] According to the International Commission on Radiological Protection (ICRP) 2007 recommendations,[18] the radiation dose from ionizing radiation imaging devices must be kept 'As Low As Reasonably Achievable' (ALARA). Utilizing CBCT with a smaller field of view (FOV) of 4–7 cm can aid in the detection of CA involving multiple teeth while adhering to these guidelines.

Cervical abrasion (CA), primarily caused by mechanical wear, can lead to the loss of tooth structure at the cervical region, dentinal sensitivity, periapical pathoses, and loss of buccal bone structure. Despite the creation of several tooth-wear indices, their lack of homogeneity and data standardization prevents effective evaluation for both preventive and treatment purposes.[19–22] Smith and Knight developed an extensive index using computer aids, pictures, and models.[23] Fares et al. introduced an improved scoring method for categorizing tooth erosions.[24] However, the subjective nature of the criteria used in qualitative approaches leads to variability in condition recording.[19,22,25] Quantitative methods for evaluating tooth wear are labor-intensive, have cumbersome grading systems, and are not sufficiently sensitive to clinical changes in tooth wear. The indirect technique, which measures tooth wear on dental casts and extracted teeth, accounts for a reference surface on the teeth that is unaffected by tooth wear.[22,26] Currently, there is no documented optimal index that combines both quantitative and qualitative assessments of cervical tooth structure loss. The Cervical Abrasion Index of Treatment Needs (CAITN)[9] which uses the CAITN probe[11] has its limitations. The CAITN probe is a customized tool designed to measure tooth abrasion more precisely. It is about 16 cm long, weighs 60 g, and features a comfortable grip with multiple finger rings. The key part for measurement is a beak with a fine needlepoint for precise placement on the tooth. The probe has a built-in scale on both sides, ranging from 0 to 20 mm, to indicate the depth of abrasion. This probe measures the buccolingual dimension quantitatively in a single dimension but does not assess the loss of tooth structure in other dimensions, remaining dentine thickness, which affects dentinal sensitivity, and pulpal status. Therefore, there is a need to introduce a new three-dimensional characterization of CA and its treatment requirements. However, some lesions cannot be detected by periapical radiographs or CBCT where the treatment is based on symptomatic relief.

4. The new descriptive classification

The new classification is based on the 3-dimensional analysis of the CA using the CBCT of the affected tooth providing its.

A-Height.

B-Buccolingual/Buccopalatal extension.

C-Circumferential Spread.

D-Remaining dentine thickness.

4.1. Height

The height of the abraded tooth structure can be analyzed using the cemento-enamel junction (CEJ) as the reference point, allowing for the identification of the lesion's extension into the root surface and coronal part (Table 1). The root is divided into three parts: the coronal one-third, middle one-third, and apical one-third. The extension is denoted using CA(A), with the superscript representing the class it belongs to. CA(A^0) indicates no or negligible loss of tooth structure at, above, or below the CEJ that cannot be detected on CBCT. CA(A^X) denotes the exclusion of the lesion due to other etiologies such as fracture, abfraction, erosion, or external cervical resorption. Fig. 2A shows a lesion extending from the CEJ to the coronal one-third of the root, classified as CA.[2]

Table 1
A-Classification on height of CA.

Classification on height (A)	Description
CA(A^0)	No/negligible loss of tooth structure
CA(A^1)	Above or at the level of CEJ
CA(A^2)	Lesion extending to coronal 1/3rd of root
CA(A^3)	Lesion extending to middle 1/3rd of root
CA(A^4)	Lesion extending to apical 1/3rd of root
CA(A^X)	Lesion excluded

4.2. Buccolingual/buccopalatal extension

The buccolingual or buccopalatal extension of the lesion can be measured using the sagittal slice of the CBCT image of the lesion. The sagittal slice should be taken at the center of the tooth, perpendicular to the long axis of the tooth, at the level of the deepest point of the lesion (Fig. 2B). The remaining buccolingual or buccopalatal structure is measured and compared with the standard tooth measurements from the CAITN index for each tooth. The dimensions obtained are used for classification, denoted as CA (Cervical Abrasion), with B representing the buccolingual or buccopalatal extension, and the superscripted numbers indicating the class of abrasion. 'CA(B^0)' in the buccolingual classification denotes no or negligible loss of tooth structure, which is undetectable on CBCT (Table 2).

For example an upper premolar with a buccolingual dimension of 6.5 mm obtained from CBCT matched with the CAITN index[9,27] to classify it as CA(B^2).Similarly, each affected tooth are classified with this classification for a better understanding of the buccolingual extension.

4.3. Circumferential spread

The circumferential spread of the lesion can help in analyzing the maximum extent of the abrasion. The angle is measured from the axial view of the CBCT (Fig. 2C). The circumferential spread classification is denoted by CA(C), with C representing the circumferential spread and the superscripted value indicating the class it belongs to (Table 3). CA (C^0) denotes no or negligible loss of tooth structure due to physiological or mechanical wear. CA(CX) indicates the exclusion of the lesion.

4.4. Remaining dentine thickness(RDT)

The remaining dentine thickness(RDT) of the tooth mainly helps in determining the treatment plan for the lesion. The RDT can be measured in either the axial view or the sagittal view(Fig. 2D). The RDT id denoted as CA(D) with superscripts of 1 and 2 representing an RDT $\geq$2 mm and $<$2 mm respectively.(Table 4)

A graphical representation of the measurement of each category has been depicted in Fig. 3A-D.

Example of Classification:For example an upper central incisor with its height extending from CEJ to more than the coronal 1/3rd of the root, buccopalatal dimension of 6.6 mm,circumferential spread of 138.2° and RDT of 2.1 mm can be denoted by CA($A^2B^2C^2D^2$).Hence considering all these factors, the treatment plan for the lesion can be easily derived from the same(Fig. 4A–D).

5. Statistical analysis

The statistical analysis of the teeth (n = 10) classified under the new

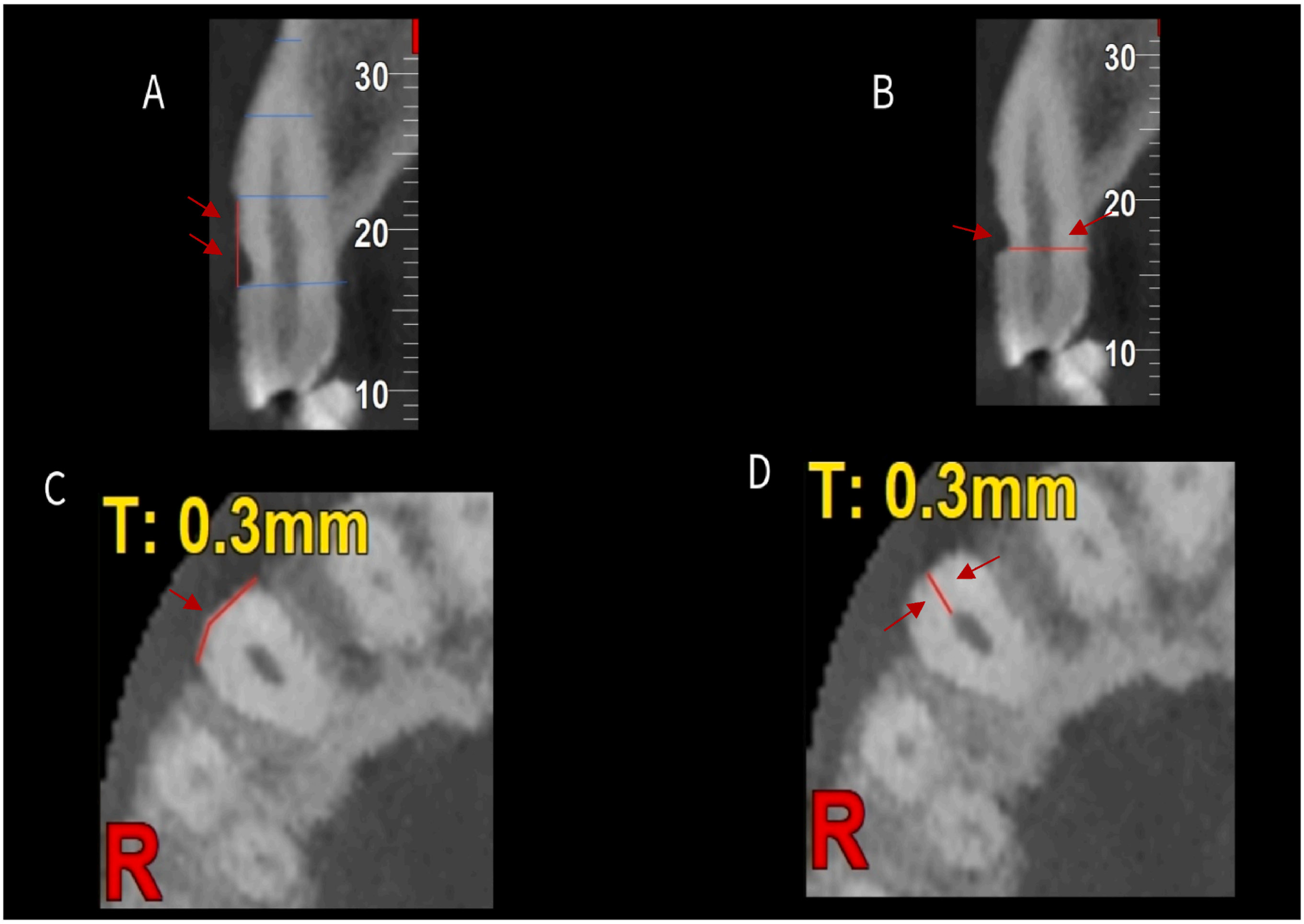

Fig. 2. (A–D) A-CBCT Sagittal view representing the height of the lesion from CEJ to coronal 1/3rd of the root with CA. **B**-CBCT Sagittal view representing the buccopalatal dimension of tooth with CA. **C**-CBCT axial view representing the circumferential spread of the tooth at CEJ with CA. **D**-CBCT axial view representing the remaining dentine thickness of a tooth with CA.

Table 2
B-Buccolingual extension classification of CA.

CLASSIFICATION OF BUCCOLINGUAL EXTENSION (B)	DESCRIPTION(mm)
CA(B^0)	No/Negligible Abrasion
CA(B^1)	Mild
CA(B^2)	Moderate
CA(B^3)	Moderately severe
CA(B^4)	Severe
CA(B^X)	Lesion Excluded

Table 3
C-Circumferential spread classification of CA.

CLASSIFICATION OF CIRCUMFERENTIAL SPREAD (C)	DESCRIPTION(^{0})
CA(C^0)	No/Negligible Abrasion
CA(C^1)	$\leq 90^\circ$
CA(C^2)	$>90^\circ$ to $\leq 180^\circ$
CA(C^3)	$>180^\circ$ to $\leq 270^\circ$
CA(C^4)	$>270^\circ$
CA(C^X)	Lesion Excluded

classification system was conducted by three examiners (AJ, AG, IG). The inter-examiner reliability for height (A), buccolingual dimension (B), circumferential spread (C), and remaining dentine thickness (RDT) (D) was assessed, and the results were obtained.

For height, none of the examined lesions extended to the apical one-third, with all lesions observed extending from the level of the CEJ to the middle one-third of the root. The inter-examiner agreement was analyzed using the Fleiss kappa value of 1, indicating 'almost perfect agreement' according to the interpretation(Supplemental data S1), with a significant p-value of 0.001.

Table 4
D-classification on RDT of CA.

Classification on RDT (D)	Description
CA(D^1)	RDT ≥ 2 mm
CA(D^2)	RDT <2 mm

Similarly, the inter-examiner reliability for RDT (D) was evaluated. The reliability for the buccolingual dimension (B) and circumferential spread (C) was assessed using the intraclass correlation coefficient (ICC), with significant p-values in all scenarios, confirming the reliability of the classification.

In the analysis of height, there was 100 % agreement between the three observers, with a Fleiss kappa value of 1.00, signifying perfect agreement. For the buccolingual dimension, the mean values assessed by Examiner 1, Examiner 2, and Examiner 3 were 6.660, 6.580, and 6.600, respectively. The ICC between the three observers was 0.993, with a significant p-value of 0.001, indicating perfect agreement. For circumferential spread, the mean values assessed by Examiner 1, Examiner 2, and Examiner 3 were 192.82, 189.52, and 190.32, respectively. The ICC between the three observers was 0.999, with a significant p-value of

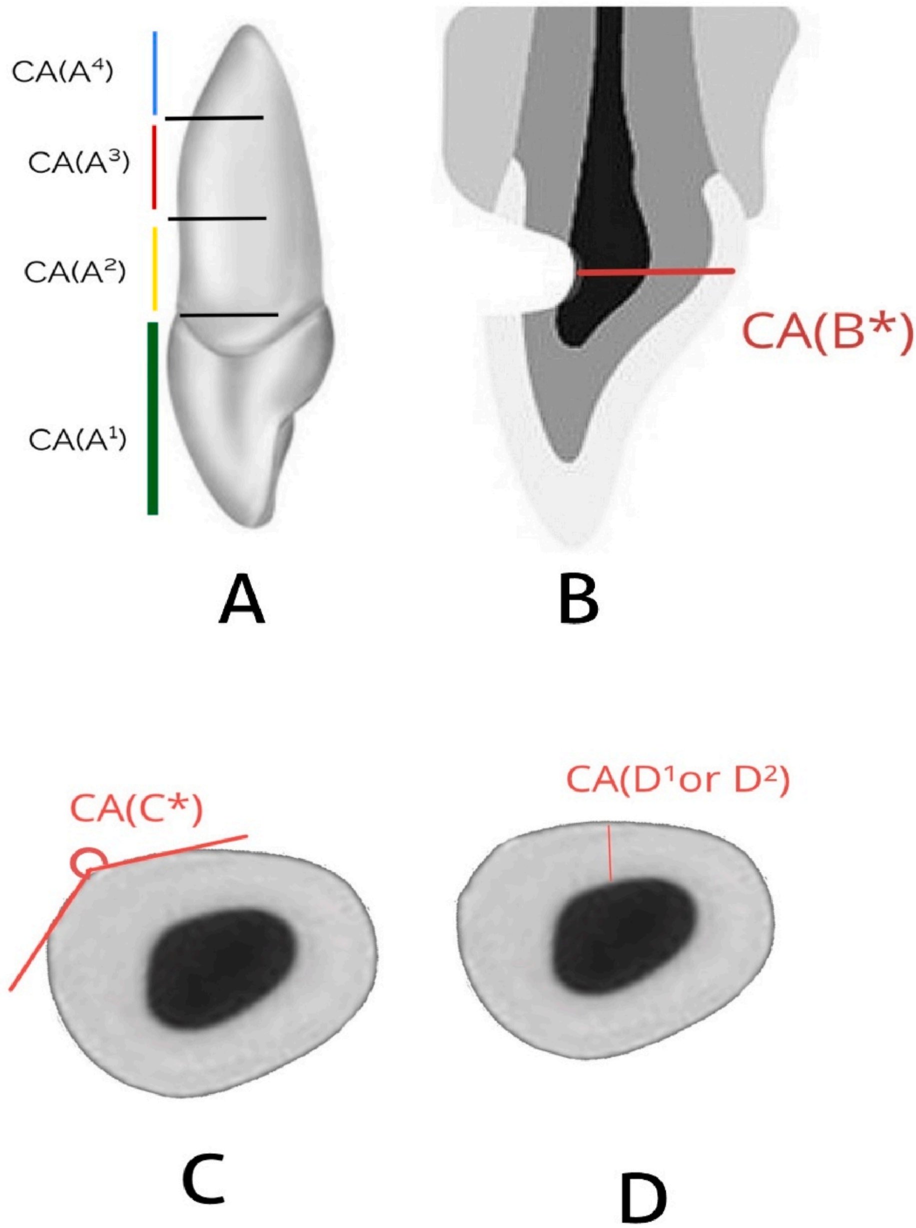

Fig. 3. *(A-D). A*-CBCT Sagittal view represents the height of the lesion on the upper central incisor. ***B***-CBCT Sagittal view representing the buccopalatal extension measuring from the deepest point of the lesion. ***C***-CBCT axial view representing the circumferential spread of the lesion. ***D***-Axial view representing the remaining dentine thickness.

0.001, indicating perfect agreement.

In the analysis of RDT, there was 100 % agreement between the three observers, with a Fleiss kappa value of 1.00, signifying perfect agreement.

The analysis of reproducibility showed that the ICC was significant for all four measurements, confirming the reliability of the new classification system.

6. Results

The Statistical analysis found the classification to be reliable and reproducible. The results for reliability were significant, with p-values of 0.001 for height (A), buccolingual dimension (B), circumferential spread (C), and remaining dentine thickness (RDT) (D). The reliability for height and RDT was examined using the Fleiss kappa, which had a value of 1.00, indicating almost perfect agreement. The buccolingual dimension (B) and circumferential spread (C) were evaluated with intraclass correlation coefficients of 0.993 and 0.999, respectively, both significant with a p-value of 0.001.

All four measurements were found to be reproducible with intra-examiner evaluation, as the intraclass correlation coefficient had a significant p-value. The classification was found to be reliable and reproducible with both intra- and inter-examiner evaluations.

7. Discussion and clinical significance

The novel three-dimensional classification of cervical abrasion using CBCT will provide a better understanding of the extension and spread of the lesion, making it more feasible to develop an effective treatment plan with a good prognosis.[28] This new classification can guide the selection of treatment options, whether surgical or non-surgical,[29] where the exposure of the root surface is treated surgically with flap surgery if possible after restoration. The height of the lesion determines its vertical extension and helps analyze periodontal involvement, which is crucial in

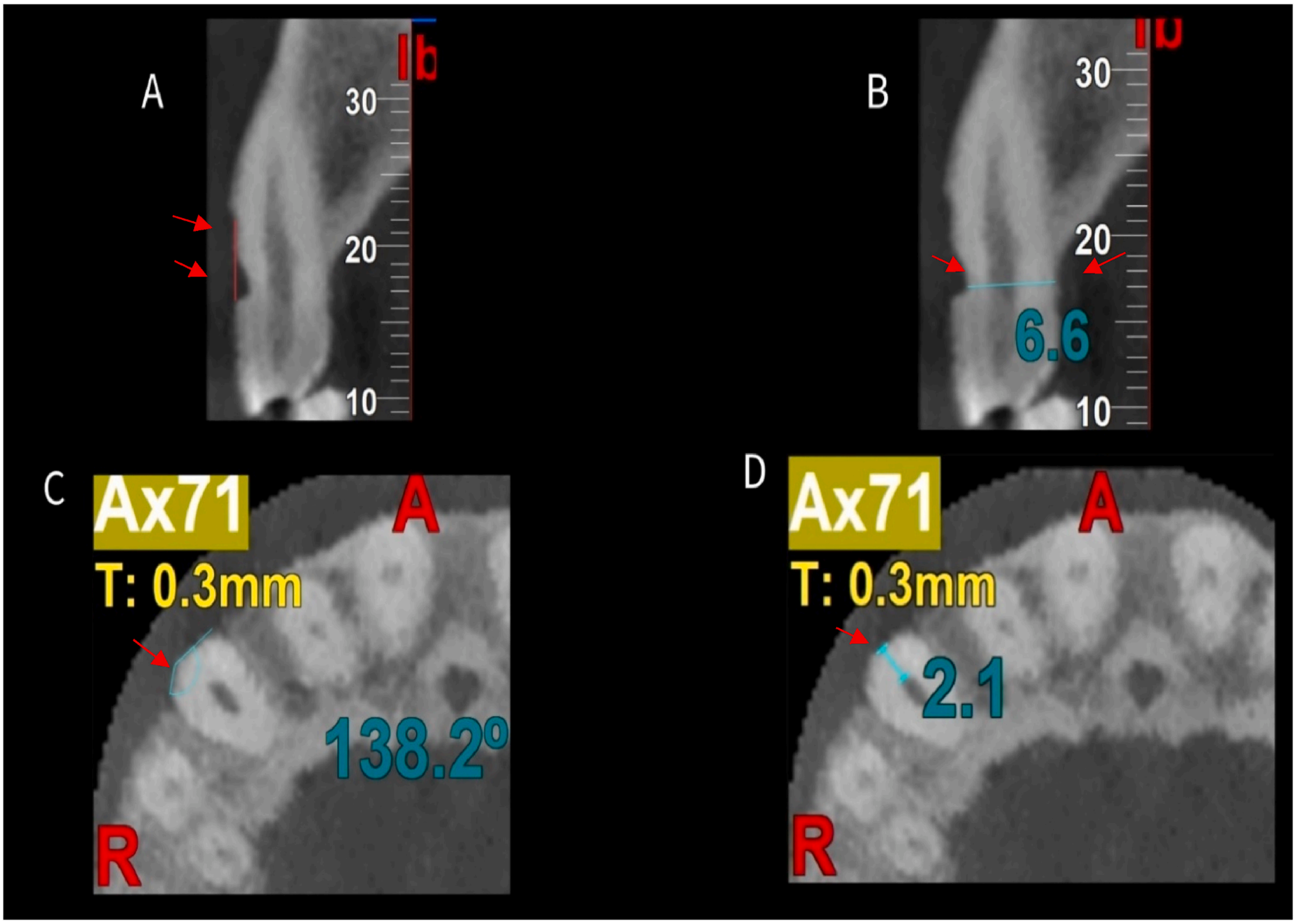

Fig. 4. (A–D). **A**-CBCT Sagittal view representing the height of the lesion of the upper central incisor. **B**-CBCT Sagittal view representing the buccopalatal extension. **C**-CBCT axial view representing the circumferential spread of the lesion. **D**-Axial view representing the remaining dentine thickness.

deciding between surgical periodontal or non-surgical restorative treatments. The remaining dentine thickness (RDT) aids in assessing potential treatments based on pulpal involvement, while the other dimensions explain the depth of the lesion, facilitating properly contoured restorations. Clinicians can use this classification to educate patients about behaviors contributing to abrasion formation and suggest preventive measures tailored to their specific abrasion profile. The new standardized classification system facilitates the comparison of studies and the development of evidence-based treatment guidelines, stimulating further research into the etiology, prevalence, and outcomes of different types of tooth cervical abrasions. Additionally, it enhances patient understanding of their condition, empowering them to take an active role in oral health management and prevention efforts.

However, the study has limitations, including the diagnostic efficacy of identifying cervical abrasions or other non-carious cervical lesions using CBCT, which has not been thoroughly investigated. Reproducibility depends on the examiner's proficiency with CBCT software. Additionally, the study's sample size was small, indicating a need for further research with larger samples. The radiation exposure from CBCT for a single tooth, especially when periapical radiographs are inconclusive, remains a concern.

8. Conclusion

A new classification of tooth cervical abrasion using Cone Beam Computed Tomography (CBCT) in endodontics could enhance diagnosis and provide detailed analysis of both hard and soft tissues. CBCT is preferred in cases involving multiple teeth or when there is uncertainty about the remaining dentine thickness (RDT) or pulpal involvement. CBCT offers a three-dimensional view of the tooth, enabling early identification of etiological factors, leading to more accurate diagnoses and improved treatment planning.

Knowledge of the amount of tooth structure lost on each surface guides the selection of appropriate restorative materials, particularly considering periodontal factors. Understanding the RDT is crucial for assessing treatment plans and accounting for pulpal status. CBCT also allows for the detection of previously unknown periapical pathoses, further enhancing treatment planning. This new classification system could open up new research avenues, potentially advancing the understanding and treatment of tooth cervical abrasions.

Author contributions

All the authors have made relevant contributions to the manuscript. All the authors have read and approved the final version of the manuscript.

Ethics statement

The following study on 3-dimensional classification of cervical abrasion did not require ethics approval.

Patients consent

The CBCT images used are purely based on demo purpose of this research and the images are deidentified at all means.

Source of funding

The study does not involve any source for funding.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jobcr.2024.08.007.

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