ORAL HEALTH

ANALYSIS OF PERIAPICAL PROCESSES AND BONE LOSS WITH 2D AND 3D RADIOLOGICAL DIAGNOSTICS

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Key words: 3D CBCT, panoramic scan, two-dimensional scan, three-dimensional scan, bone loss

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Abstract

In recent years, dental practice has increasingly given preference to three-dimensional versus two-dimensional X-ray diagnostics. The three-dimensional view in layers (sections) and the use of modern software allow for an incomparably better visualization of a patient's oral cavity status compared to conventional orthopantomographic X-ray devices. Objective: The main objective of this study was to identify the difference between three-dimensional and two-dimensional radiological diagnostics and to demonstrate the advantages of 3D X-ray by presenting several clinical cases. Bone loss, as well as the presence of periapical processes and their actual size were analyzed, and the parameters were compared on two-dimensional and three-dimensional images. Materials and method: The examination took place at the 3D-RDG (Dental X-ray Diagnostics 3D-RTG Dental Imaging Skopje) Center in Skopje. To achieve the set goal, we made a radiological comparison of two-dimensional and three-dimensional X-ray images in 73 subjects, of which 40 (54.79%) teeth in the upper jaw and 33 (45.21%) teeth in the lower jaw. All subjects were scanned with the same X-ray device - Green X, which is from the latest generation of X-ray devices, with a minimum dose of radioactive radiation - 2.9 sec. for 3D-CBCT and 3.9 sec. for panoramic imaging. For detailed analysis and diagnosis of the cases, the most modern and sophisticated software, EzDent-i and Ez3D-i, were used, offering various fields of view projections. Results: Of the 73 analyzed teeth, a periapical process was diagnosed in 52.05% of teeth using 2D and in all teeth using 3D. The actual size of the periapical process was significantly larger on three-dimensional radiography compared to two-dimensional radiography ($p<0.0001$). Bone loss on 3D was recorded in 50% of maxillary teeth and in 33% of mandibular teeth. Conclusion: Three-dimensional radiography provides much clearer diagnostic values in the diagnosis of periapical changes compared to two-dimensional images. Three-dimensional radiography provides clearer results in terms of the actual size of periapical changes. Bone loss can be reliably diagnosed only with three-dimensional radiography, and is more common in the upper jaw.

ОРАЛНО ЗДРАВЈЕ

АНАЛИЗА НА ПЕРИАПИКАЛНИ ПРОЦЕСИ И КОСКЕН ГУБИТОК СО 2D И 3D РАДИОЛОШКА ДИЈАГНОСТИКА

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Клучни зборови: 3D CBCT, панорамска снимка, дводимензионална снимка, тридимензионална снимка, коскен губиток

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Печатарски права: ©2025. Марина Ефтимоска, Марио Јурхар, Василка Ренџова, Емилија Стефановска, Стевица Ристовска. Оваа статија е со отворен пристап дистрибуирана под условите на нелокализирана лиценца, која овозможува неограничена употреба, дистрибуција и репродукција на било кој медиум, доколку се цитираа торигиналниот(ите) автор(и) и изворот.

Конкурентски интереси: Авторот изјавува дека нема конкурентски интереси.

Извадок

Во последните години од стоматолошката практитка, сè повеќе се дава предност на тридимензионалната наспроти дводимензионалната РДГ дијагностика. Тридимензионалниот приказ по слоеви, односно пресеци, и примената на современиот софтвер, овозможува неспоредливо подобра визуелизација на статусот во оралната празнина на пациентот, за разлика од конвенционалните ортопантомографски РДГ апарати. Главна цел на овој труд беше да се воочи разликата помеѓу тридимензионалната и дводимензионалната радиолошка дијагностика и да се докаже предноста на 3D РДГ, преку приказ на повеќе клинички случаи. Беше анализиран коскен губиток како и присуство на периапикални процеси и нивната реална големина, а параметрите беа компарирани на дводимензионална и на тродимензионална снимка. Материјали и методи: Испитувањето се одвиваше во 3D-RDG (Рендген-дијагностика за заби 3Д-РТГ Дентал Имицинг Скопје), центарот во Скопје. За реализација на поставената цел направивме радиолошка споредба на дводимензионална и тридимензионална РДГ снимка кај 73 испитаници, од кои 40 (54.79%) заби во горна вилица и 33 (45.21%) заби во долна вилица. Сите испитаници беа снимани со ист РДГ апарат - Green X, кој е од последната генерација РДГ апарати, со минимална доза на радиоактивно зрачење, и тоа 2.9 сек. за 3D-CBCT и 3.9 сек. за панорамска снимка. За детална анализа и дијагноза на случаите се применуваа најсовремени и софистицирани софтвери, EzDent-i и Ez3D-i, кои овозможуваат различни проекции на видното поле. Резултати: Од анализираните 73 заби, периапикален процес беше дијагностициран кај 52.05% од забите на 2D и кај сите заби на 3D. Реалната големина на периапикалниот процес беше сигнификантно поголема на тридимензионалната рендгенографија, споредено со дводимензионалната рендгенографија ($p<0.0001$). Коскен губиток на 3D беше регистриран кај 50% од забите во горната вилица и кај 33% од забите во долната вилица. Заклучок: Тридимензионалната рендгенографија дава многу појасни дијагностички вредности при дијагноза на периапикалните промени за разлика од дводимензионалните снимки. Појасни резултати во однос на реалната големина на периапикалните промени дава тридимензионалната рендгенографија. Коскениот губиток со сигурност може да се дијагностицира само на тридимензионална рендгенографија, а тој се среќава почесто во горната вилица

Introduction

Apical periodontitis represents the primary alteration linked to infection within the root canal's microbial environment.

The accepted reference standard for radiological detection of a periapical process is the periapical radiograph. In the early stages of apical periodontitis, bone resorption may be minimal or covered by other anatomical-morphological structures. Cone-beam computed tomography (CBCT), as an additional or primary diagnostic aid, allows detection of the same change even before it becomes visible on a conventional periapical radiograph, that is, in the early stage. Patel et al.[1] and Pineda[2] in their research found that diagnosing with the sensitivity of the CBCT beam is 34-54.2% higher compared to intraoral radiography for detecting periapical changes. Dutra[3] in his study emphasized that the highest precision in diagnosing periapical changes was achieved with CBCT. The difference between a nasopalatine cyst and a periapical process was explored by Faitaroni4, who pointed out that CBCT provided a detailed, high-resolution image that helped in establishing the initial diagnosis and therapy planning. However, histopathological analysis is essential in the differential diagnosis. In a long-term study, Sharma[5] concluded that the healing process of the tooth was significantly better with the use of CBCT due to the initial precise diagnosis, which was substantially higher compared to conventional retroalveolar radiographs.

Maillet[6] examined the correlation between infected canals in upper molars and maxillary sinusitis. In his study, he made a distinction between two-dimensional and three-dimensional diagnostics and demonstrated that the sensitivity of the CBCT beam was 50% greater than that of retroalveolar radiographs. Of 135 cases examined, 98 maxillary sinusitis cases were caused by dental issues, while 37 were of non-odontogenic origin. Cone-beam computed tomography was proven to be the best diagnostic aid, as shown in Low's study[7], which focused on the overall pathology of teeth, root canal filling revisions, expansion of the periapical process toward the maxillary sinuses, thinning, and erosion of the sinus floor, untreated canals, etc. Burgos[8] suggests that presenting the benefits and capabilities of CBCT for precise diagnostics through videos can help patients agree to this type of imaging at the start of treatment (research in the U.S. Army). Cui[9] in his study emphasized that the combination of conventional radiography and CBCT provided significantly better results in endodontic therapy over a longer period. Songa[10] aimed to demonstrate the advantages of CBCT in his case of a 21-year-old patient with expansion of a periapical process in the lower first molar and affected furcation. The distal root of this tooth had bone resorption only on the lingual side. This diagnostic precision would not have been possible with a two-dimensional radiograph.

In her 5-year study, Ritika[11] stated that with the help of cone-beam computed tomography, compared to 2D radiographs, periapical changes can be more accurately monitored during their healing. A similar interpretation has been provided by Tom[12]. In his research, he highlighted that 2D did not provide an accurate image in terms of the actual size of the peri-

apical changes. Cone-beam computed tomography is recommended as the sole method for the precise diagnosis of osseous defects, which occur more frequently on the labial/buccal side, compared to the palatal/lingual side[13]. This was confirmed by Bayat[14] in his study. Through his cases, CBCT has proven to be superior compared to 2D radiographs when it comes to the involvement of bone defects. The amount of bone tissue loss, whether horizontal or vertical, can only be diagnosed and determined with 3D CBCT[15]. Assiri[16] points out that CBCT is the most precise of all radiographic methods for diagnosing periapical lesions, osseous defects, and furcation involvement.

The main goal of this paper was to highlight the difference between three-dimensional and two-dimensional radiological diagnostics and to demonstrate the advantages of 3D X-rays by presenting multiple clinical cases. Bone loss, as well as the presence of periapical processes and their actual size were analyzed, and the parameters were compared between two-dimensional and three-dimensional imaging.

Materials and methods

In our study, to achieve the set goal, a Green X X-ray machine from the latest generation was used, with a minimal dose of radioactive radiation, specifically 2.9 seconds for 3D-CBCT and 3.9 seconds for panoramic imaging.

X-ray machines of this generation represent a 4-in-1 system and have the capability to take four types of images:

1. Cone-beam computed tomography (CBCT) with different fields of view (FOV)
2. Cephalometric scan
3. Two-dimensional digital panoramic (half panorama, left or right, two-dimensional projection of the TMJ, as well as maxillary sinuses)
4. Model scan - with the further possibility of adapting the model to a patient's 3D image, in order to create implant guides.

The study was conducted at the 3D-RDG (Radiology Diagnostics for Teeth) Center in Skopje (a branch of PHI-Polyclinic Secondary Level EDG-2 Gevgelija).

The segmented, full 3D-CBCT images, as well as the orthopantomogram, were taken using the Green X digital X-ray machine.

For detailed analysis and diagnosis of the cases, the most modern and sophisticated software, EzDent-i and Ez3D-i, were used, which offered various projections of the visible field.

Tests were conducted on 73 teeth, of which 40 (54.79%) were in the upper jaw and 33 (45.21%) in the lower jaw. The anatomical-morphological characteristics of the teeth and their pathologies were analyzed on 2D and 3D X-rays (two-dimensional and three-dimensional radiography).

3D - CBCT full and segmented image procedure

The patient enters the X-ray room and stands upright, with the head stabilized and aligned to the facial midline. The therapist leaves and closes the door of the X-ray room, pressing the button to start the exposure in a duration of 2.9 seconds. After the image is taken, the patient is released from the X-ray machine.

2D - Panoramic image procedure

The patient enters the X-ray room and stands upright, with the head stabilized and aligned to the facial midline, the Frankfurt plane, and the canine line. The therapist leaves and closes the door of the X-ray room, pressing the button to start the exposure in a duration of 3.9 seconds. After the image is taken, the patient is released from the X-ray machine. After the images are taken, a so-called 3D *versus* 2D analysis is performed, where radiographic signs from both images are compared.



Image 1: Positioning of the patient - canine line, interincisal line, and the line corresponding to the Frankfurt plane

Endo – software

Preoperative segmented imaging with a 4x4 field of view represents an excellent diagnostic method in the treatment of teeth from an endodontic perspective. The voxel size in the resolution of this image is 0.49 micrometers.

The sophisticated software and the "endo mode" tool allow for a 360-degree rotation around the tooth, marking of the root canals, determination of periapical lesions, differential diagnostic separation of root fractures or lateral canals, determination of the exact root morphology, and working length of the canals. With marked canals, the therapist immediately knows how to proceed, i.e., through a treatment plan, to minimally invasively treat the tooth from an endodontic perspective. After the images were taken, we proceeded to a so-called 3D *versus* 2D analysis, in which radiographic signs were compared from both perspectives.

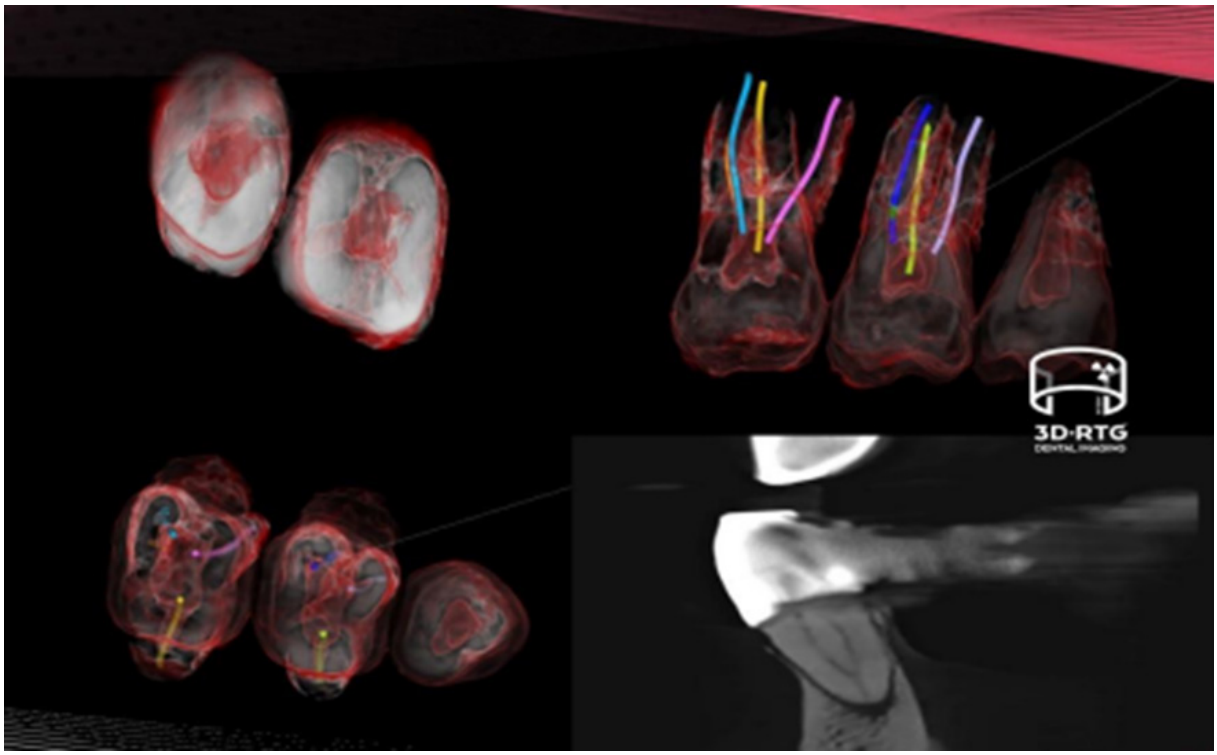


Image 2: Endo-mode – as part of the sophisticated Ez3D-i software. The corresponding tooth structures are marked with color that is updated according to the tissue density. The canals of the relevant teeth are also outlined.

Results:

In this study, 73 teeth were analyzed, of which 40 (54.79%) were in the upper jaw and 33 (45.21%) were in the lower jaw (Table 1).

Table 1: Distribution of teeth from the upper and lower jaws

Jaw	n (%)
Upper	40 (54.79)
Lower	33 (45.21)

The anatomical and morphological characteristics of the teeth and their pathologies were analyzed using 2D and 3D.

A periapical process was diagnosed in 38 (52.05%) teeth using 2D and in all teeth using 3D (Table 2, Figure 1).

The proportion of teeth with a periapical process on 2D was 38/73 = 0.521 or 52.1%. The proportion of teeth with a periapical process on 3D was 73/73 = 1 or 100%. The difference in the proportion of teeth with a periapical process detected on two-dimensional and three-dimensional radiography was statistically significant, with $p < 0.0001$, and was significantly higher on 3D (Table 2, Figure 1).

Table 2: Presence of periapical process – 2D *versus* 3D

Periapical process	RTG	
	2D n (%)	3D n (%)
yes	38 (52.05)	73(100)
no	35(47.95)	0

McNemar test p<0.00000

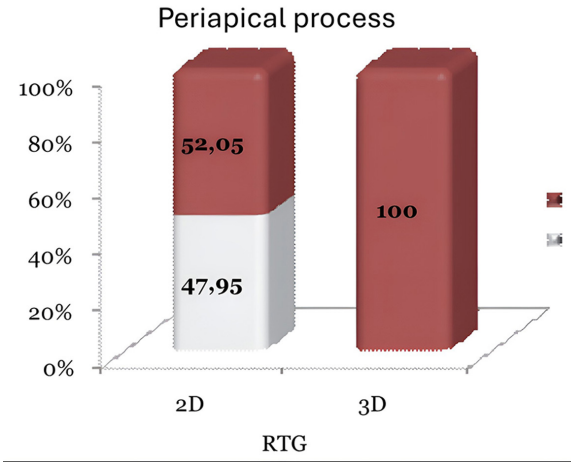


Figure 1: Illustration of periapical process findings on 2D and 3D

The average size of the periapical process on 2D was 1.7±0.6 mm (Table 3, Figure 2). Half of the teeth showed periapical lesions larger than 1.75 mm (Table 3).

Table 3: Presence of periapical process – 2D *versus* 3D

Actual size of the periapical process 2D	Statistical parameter
n	38
mean ± SD	1.69 ± 0.6
min- max	0.5 – 3.0
median (IQR)	1.75 (1 – 2)

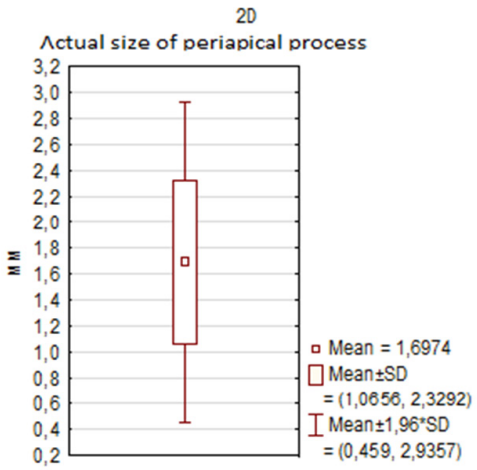


Figure 2: actual size of the periapical process – 2D

The average size of the periapical process on 3D was 3.6±1.4 mm, while half of the teeth showed periapical lesions larger than 3 mm (Table 4, Figure 3).

Table 4: Presence of periapical process – 2D *versus* 3D

Actual size of the periapical process – 3D	Statistical parameter
n	73
mean ± SD	3.59 ± 1.4
min- max	1.5 – 8
median (IQR)	3 (2.5 – 4)

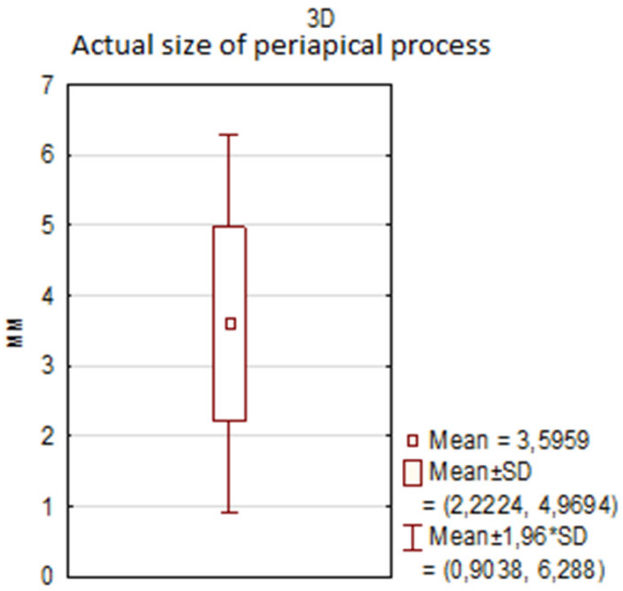


Figure 3: actual size of the periapical process 3D

The actual size of the periapical process was significantly larger on three-dimensional radiography compared to two-dimensional radiography (p<0.0001). The average size of the periapical process was 1.7 ± 0.6 mm on 2D and 4.35 ± 1.3 mm on 3D (Table 5, Figure 4).

Table 5: Comparison of the actual size of the periapical process – 2D *versus* 3D

Radiography	Statistical parameter		p-level
	n	mean ± SD	
Actual size of the periapical process 2D		1.69 ± 0.6	t=16.05 ***p=0.000000
Actual size of the periapical process 3D	38	4.35 ± 1.3	

t (Student t-test)
***sig p<0.0001

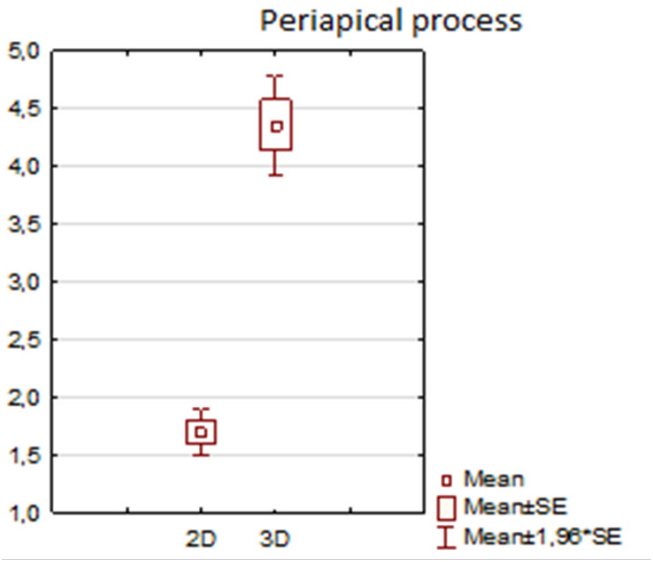


Figure 4: Illustration of the actual size of the periapical process – 2D *versus* 3D

2D radiography did not present bone loss in any tooth, while 3D X-ray diagnosed bone loss in 31 (42.47%) teeth. The difference in the proportion of teeth with bone loss, depending on the radiographic technology, was statistically significant ($p<0.000001$).

3D radiography significantly more frequently detected bone loss compared to 2D (Table 6, Figure 5).

Table 6: Bone loss – 2D *versus* 3D

Bone loss	Radiography	
	2D	3D
Yes	0	31 (42.47%)
No	73 (100%)	42 (57.53%)

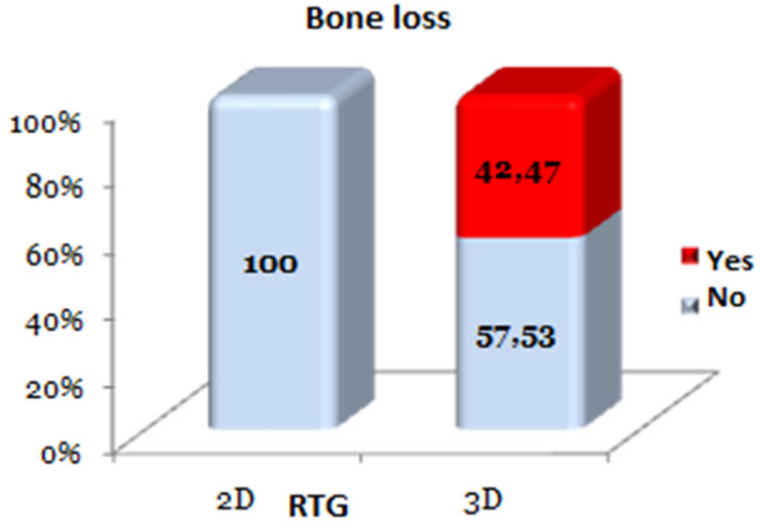


Figure 5: Illustration of bone loss on 2D and 3D

3D registered bone loss in 20 (50%) teeth from the upper jaw and in 11 (33.33%) teeth from the lower jaw. The difference in the prevalence of bone loss, depending on the location of the teeth in the upper or lower jaw, was not statistically significant, but it was more common in the upper jaw (0.15) (Table 7, Figure 6).

Table 7: Bone loss in teeth from the upper and lower jaw

Radiography	Jaw			p-level
	n	upper n (%)	lower n (%)	
Yes	31	20 (50)	11 (33.33)	X^2=2.0 p=0.15
No	42	20 (50)	22 (66.67)	

X^2(Pearson Chi-square)

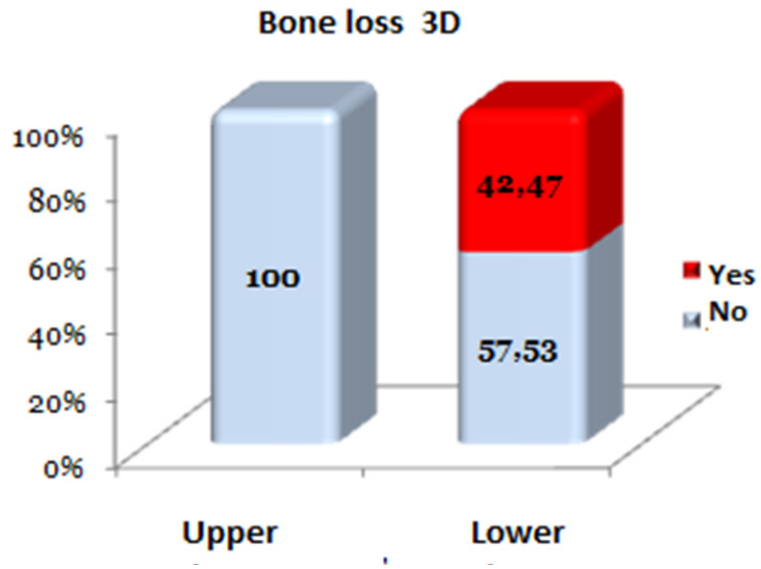


Figure 6: Illustration of bone loss on 3D in the upper and lower jaw expressed in %

Discussion

In the past decade, the question of whether patients need to undergo three-dimensional radiography has been increasingly discussed in dental practice.

Dentists debate over this question due to concerns that patients would be exposed to a higher dose of radioactive radiation.

With the innovation of digital radiography, radioactive radiation has been minimized.

A new trend involves CBCT (Cone Beam Computed Tomography) devices of the green generation (Green CT) and imaging according to the ALARA principle.

1Sv (Sievert) is a unit of measurement for the absorbed dose of radioactive radiation.

This radiation dose is high and is considered to potentially cause pathological changes (undesired cell division) in the tissues of patients.

Panoramic radiographs and three-dimensional radiography are characterized by radioactive radiation ranging from 15 to 30 microsieverts.

One Sievert (Sv) is equivalent to 1,000,000 microsieverts, meaning the pathological threshold is far beyond the point where it could be questioned whether the imaging is dangerous for the patient's health. Smart devices from the green generation are characterized by an even smaller dose of radioactive radiation (less than 15 microsieverts).

Through sophisticated software, by entering patient details, radiographic devices automatically adjust the radioactive dose based on bone density, which changes over the years. This ensures that patients absorb the minimum dose necessary to accurately image the anatomical and morphological structures of interest.

As the device produces the beam and it penetrates into patient tissues, the device loses its power and fades until the therapist enters the radiography room to release the patient from the device. This fact indicates that radiography is safe for the therapist and all clinical staff involved in radiographic diagnostics. Considering these improvements, radiography today can be considered a completely safe method for top-notch diagnostics and flawless therapy for patients. Three-dimensional versus two-dimensional radiographic diagnostics represents a current and interesting comparison regarding therapy outcomes in dental practice. We are increasingly turning to the use of 3D CBCT for initial and accurate diagnosis. This represents a new trend and ergonomic principle in dental treatment.

The therapist is immediately familiar with the complete image of the area of interest and is prepared to proceed with accurate therapy. This method enables therapists to protect patients from ineffective therapy and reduce the amount of time patients spent in the dental chair.

The significantly higher accuracy of three-dimensional radiography is also demonstrated by comparing voxels and pixels. The fact that the resolution of the three-dimensional image is measured in voxels, which are characterized by the same size in all directions, points to the greater diagnostic value compared to pixels in two-dimensional radiographs, where only height and length are characteristic.

Periapical Changes

From the 73 teeth analyzed in this study, a periapical process was diagnosed in 38 (52.05%) teeth on 2D and in all teeth on 3D.

The proportion of teeth with a periapical process on 2D was 38/73 = 0.521 or 52.1%. The proportion of teeth with a periapical process on 3D was 73/73 = 1 or 100%. The difference in the proportion of teeth with a periapical process detected on two-dimensional and three-dimensional radiography was statistically significant, with $p < 0.0001$, and was significantly greater on 3D.

(Table 2, Figure 1)

Similar results were presented by Patel1, who stated that periapical changes could be diagnosed with CBCT even before they became visible on a conventional two-dimensional image, in the early stage.

On the other hand, Pineda et al.2 in his research found that the diagnosis using the sensitivity of the CBCT beam was by 34-54.2% more accurate compared to two-dimensional imaging for detecting periapical changes.

Patil et al.15 pointed out that periapical changes, which could not be seen on 2D, were visible on 3D. This study included 178 teeth, of which a periapical process was observed in 31.5% on 2D and 52.2% on CBCT.

The average size of the periapical process on 2D was 1.7 ± 0.6 mm (Table 3, Figure 2).

The average size of the periapical process on 3D was 4.35 ± 1.3 mm (Table 4, Figure 3).

The actual size of the periapical process was significantly larger on three-dimensional radiography compared to two-dimensional radiography ($p < 0.0001$) (Table 5, Figure 4).

These results are similar to those presented by Ordinola-Zapata17, who stated that the volume of periapical changes in endodontically treated and untreated teeth could only be monitored with 3D CBCT. Two-dimensional radiography does not have this capability.

Unlike all other radiographic methods, CBCT is characterized by the highest sensitivity regarding periodontal defects18.

Fernanda19 emphasized that diagnostics based on 2D for determining the exact size of periapical changes is limited and should not be used for scientific research.

Osseous Defects

2D radiography did not show bone loss in any tooth, whereas 3D CBCT diagnosed bone loss in 31 (42.47%) teeth. The difference in the proportion of teeth with bone loss, depending on the radiographic technology, was statistically significant ($p < 0.000001$) (Table 6, Figure 5).

3D radiography significantly more frequently detected bone loss compared to 2D. Bone loss on 3D was registered in 20 (50%) teeth from the upper jaw and in 11 (33.33%) teeth from the lower jaw. The difference in the prevalence of bone loss, based on the location of the teeth in the upper or lower jaw, was not statistically significant, but it was more common in the upper jaw (0.15) (Table 7, Figure 6).

Gambarini20 underscores that preoperative CBCT accurately diagnoses whether there is fenestration or not. According to Urbani's study21, fenestrations are more common in the maxilla compared to the mandible. Cone-beam computed tomography is recommended as the only method for the precise diagnosis of osseous defects. These defects occur more frequently on the labial/buccal side, compared to the palatal/lingual side13.

Conclusions

Based on the results obtained in this study, the following conclusions can be drawn:

1. The comparative two-dimensional *versus* three-dimensional radiographic analysis, in relation to the presence of periapical processes, showed that three-di-

mensional radiography provided much clearer diagnostic values compared to two-dimensional images when diagnosing periapical changes.

2. When analyzing and diagnosing the actual size of periapical changes, the size was significantly larger on 3D. Therefore, three-dimensional radiography provides clearer results in relation to the actual size of periapical changes.
3. When analyzing radiographic images of the same teeth and comparing 2D and 3D images, a statistically significant difference was found regarding bone loss from the alveolar ridges; bone loss was detected using 3D, while no cases were seen using 2D. We can conclude that bone loss can certainly be diagnosed only with three-dimensional radiography.
4. Three-dimensional radiography revealed that bone loss was more frequently observed in the upper jaw than in the lower jaw from the analyzed teeth, Bone loss was more common in the upper jaw due to the spongy tissue of the maxillary alveolar ridge, as opposed to the compact portion of the mandibular alveolar ridge.

In general, it can be concluded that the limitations that arise when diagnosing with two-dimensional radiography are not present in 3D. Exposure to additional radiographic radiation is avoided by using 3D CBCT as an initial image, leaving behind two-dimensional projections.

With modern digital three-dimensional radiographic diagnostics, we achieve the highest diagnostic values, minimal exposure of patients to radioactive radiation, and high-quality and well-planned endodontic therapy.

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