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ORIGINAL ARTICLE

Effect of radiation dose on the prevalence of apical periodontitis—a dosimetric analysis

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Abstract
Objectives The objective of this study is to analyse the effect of the radiation dose of oral radiotherapy for cancer on the presence of apical periodontitis in patients without dental pre-screening or specific preventive measures.
Materials and methods All selected patients had been diagnosed with cancer in the head and neck region and presented in the dental clinic post radiotherapy with side effects (mainly radiation caries). The panoramic radiographs of these patients were examined for several parameters, including tooth decay and apical periodontitis. The total radiation dose per tooth was determined.
Results A total of 36 patient files were included, which accounted for 628 teeth to be scored. Tooth decay was present in 88.2% of teeth. Radiographic signs of apical periodontitis were found in 9.1% of the teeth. Teeth with apical periodontitis had significantly more caries present. The radiation dose was significantly higher for teeth with apical periodontitis (37.2 vs. 24.9 Gy). Binary logistic regression found the radiation dose to be the only explanatory variable in the presence of apical periodontitis.
Conclusions This study found that in zones with higher radiation dose, inflammation of the jawbone due to bacterial infection of the root canal is more likely to develop. This is probably due to bone changes post radiotherapy.
Clinical relevance An increase of this prevalance of apical periodontitis in irradiated bone found in this study needs to be taken into account in the dental evaluation before the start of radiotherapy.

Keywords Head and neck cancer · Radiotherapy · Apical periodontitis · Root canal · Side effects · Bone inflammation

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Introduction

The side effects of radiotherapy in the head and neck region have extensively been described in the literature. The main oral side effects are caused by irradiation damage to the salivary glands and the jawbone. Xerostomia is one of the most frequently reported side effects by patients, as it has a major impact on the quality of life [1, 2]. A commonly reported sequel of xerostomia is an increased susceptibility for tooth decay. In patients irradiated in the head and neck region, this is typically seen as radiation caries. This is rapidly progressing decay of the teeth following a shift in the oral flora to a more acidogenic and cariogenic oral flora [3–8]. This kind of tooth decay, if not treated, involves the root canal space within a matter of months, exposing it to the oral environment. This leads to necrosis of the pulp tissue, bacterial colonisation of the root canal space, supposedly bacterial ingress into the jawbone and subsequent periradicular inflammation of the jawbone with localised bone destruction (apical periodontitis) [9–12]. It is important to realise that the periradicular infection is not self-resolving, as the infection is mainly localised inside the root canal and the absence of vital tissue inside the tooth impairs the immune response.

In a previous study, we found that 7.8% of teeth in patients irradiated in the head and neck region were affected by apical periodontitis [13]. This was not significantly

different from a control population, although the caries rate (indicating invasion of the root canal space by oral bacteria) was significantly higher (86.2% vs. 13.9%). We could not explain this lower than expected percentage of apical periodontitis. This difference could have been attributed to bacterial shifts in the oral cavity and root canal, resulting in a less pathogenic flora and/or a change in cellularity and vascularisation of irradiated bone.

The aim of this retrospective study was to analyse the effect of the radiation dose per tooth on the presence or absence of apical periodontitis in patients irradiated in the head and neck region with lack of specific dental prevention.

Materials and methods

Sample selection

All patients selected in this study consulted the dental service in 2005 for oral radiotherapy, minimally 6 months post radiotherapy. The year 2005 was chosen because this was the last year where there was no systematic collaboration of the dental school with the oncologic team in the prevention of the side effects in this patient group. Only those patients were selected that received no dental pre-screening prior to the start of radiotherapy, no dental follow-up post radiotherapy and thus did not apply specific dental preventive measures.

All included patients received external radiotherapy in the head and neck region, of which some were also previously surgically treated. All files of patients that did receive dental treatment or dental preventive measures post radiotherapy were discarded, as well as files without panoramic radiograph.

Radiographic examination

All panoramic radiographs were taken with a Kodak 8000 C Digital Panoramic and Cephalometric System (Carestream Dental, Toronto, Canada). Two authors (GH and RDM) evaluated each tooth independently from each other. If disagreement existed, a joint evaluation was made until a consensus was reached. Inter- and intraobserver agreement were both high for apical periodontitis (kappa values 0.82 and 0.91, respectively), based on scoring 100 teeth. The criteria for the radiographic categorization of all teeth were as follows (multi-rooted teeth were classified according to the root exhibiting the most severe periapical condition):

- The periapical assessment was conducted using the five-point "Periapical Index" scale as proposed by Orstavik [14] and adapting it to panoramic radiographs using the same radiographic criteria [15]. Scores 3 to 5 were classified as apical periodontitis.
- The radiographic coronal condition of each tooth was noted and classified as:
  - *Filling:* restoration of the coronal part of the tooth, with a plastic restorative material.
  - *Crown:* restoration of the coronal part of the tooth with a cast restoration or a porcelain jacket crown.
  - *Caries:* radiographically visual tooth decay.
  - *Root canal filling:* the radiographic presence of a root canal filling was noted.

Radiation dose determination

All patients were irradiated with a single-isocentre three-field technique or intensity modulated radiotherapy. The delivered dose varied from 66.0 to 70.2 Gy.

From each selected patient, the radiation oncologist (GDM) performed a dosimetric analysis to retrieve the total radiation dose per tooth. The files from which the radiation dose could not be retrieved were discarded. This resulted in 36 patient files to be analysed.

Statistical analysis

All data were processed and analysed using SPSS 10.0 for Windows (SPSS Inc., Chicago, IL, USA). Binary logistic regression and life table analysis were performed.

Results

A total of 36 patient files were scored. The group constituted of 33 males and 3 females. The mean age was 52.2±8.9 years. Table 1 describes the tumour data according to localisation, histological typology, and TNM staging.

A total of 628 teeth were scored radiographically. Of the theoretically 32 teeth per person, a mean of 17.4 teeth was present in each subject. In 449 teeth (71.5%), no radiographic signs of prior dental treatment were visible, 152 teeth (24.2%) were restored with a filling and 27 teeth (4.3%) were restored with a crown. Fifty teeth (8.0%) were endodontically treated. Caries was present in 88.2% of teeth (n=554). This was 88.2% for unrestored teeth, 93.4% for filled teeth, and 59.3% for crowned teeth. Radiographic signs of apical periodontitis were present on 9.1% of teeth (n=57). No significant difference was found in prevalence of apical periodontitis between mandibula and maxilla (11.8% vs. 8.13, $\%\chi^2$=1.760, p>0.05).

Table 2 describes the coronal condition of the teeth in relation to the periapical condition. Of the 571 teeth without apical periodontitis, 498 (87.2%) showed radiographic signs of caries, of the 57 teeth with apical periodontitis, 56

Table 1 Tumour localisation, histology, staging, and lymph nodes involved in the patient sample (n=36)

Localisation			
Orofarynx	14		
Hypofarynx	6		
Rhinofarynx	2		
Oral cavity	9		
Glottis	3		
Cup	2		
Histology			
Badly differentiated epidermoid epithelioma	14		
Moderately differentiated epidermoid epithelioma	18		
Good differentiated epidermoid epithelioma	3		
Sarcoma	1		
Staging (sarcoma excluded)			
	N_0	N_1	N_2
T_1	3	1	
T_2	3	2	6
T_3	6		
T_4	5		6
rT_x			1
Cup T_x			2

(98.3%) showed radiographic signs of caries. Thus, teeth with apical periodontitis had a significantly higher rate of caries (98.3% vs. 87.2%; χ^2=6.066, p<0.05).

Table 3 gives an overview of the radiation dose per tooth according to different parameters. There was no statistically significant difference of radiation dose per tooth between maxilla and mandibula. The difference in radiation dose between teeth with normal periapical condition and presence of apical periodontitis was statistically significant (24.9 vs 37.2 Gy; t=2.823, p<0.01).

Table 2 Relation between coronal and periapical condition of the teeth (n=628)

Coronal condition		Periapical condition			
		Normal		Apical periodontitis	
		n	%	n	%
Untreated					
	−ca	52	9.1	1	1.8
	+ca	357	62.5	39	68.4
Filling					
	−ca	10	1.8	0	0
	+ca	126	22.1	16	28.1
Crown					
	−ca	11	1.9	0	0
	+ca	15	2.6	1	1.8
Total					
	−ca	73	12.8	1	1.8
	+ca	498	87.2	56	98.2

−*ca* caries free, +*ca* caries present

Table 3 Radiation dose per tooth according to different parameters

Parameters	Radiation dose (Gy)	
	Mean	SD
Overall	26.0	31.6
Location		
Maxilla	24.8	30.8
Mandibula	27.1	32.4
Periapical condition*		
Normal	24.9	31.6
AP	37.2	29.3
*p<0.05		
Caries*		
No caries	18.9	26.5
Caries	27.0	32.1

*p<0.05

A binary logistic regression was performed to determine the explanatory variables that could explain the periapical condition. The only variable that had a statistically significant influence on the periapical condition was the radiation dose (Table 4).

Discussion

The side effects of radiotherapy in the head and neck region are commonly known [16]. The most important ones linked with oral health are the effects of radiotherapy on the salivary glands and on the bone. Irradiation of the salivary glands, even at low levels, destroys the acini and decreases the production of saliva. As saliva contains several defence mechanisms against tooth demineralization and caries, these patients are very susceptible to tooth decay [17]. This aggressive form of tooth decay evolves rapidly and often involves the pulpal space. As a result, the pulp spaces will get invaded with bacteria [18].

The use of panoramic radiographs for detection of apical periodontitis has been a point of discussion in the literature.

Table 4 Regression table of the periapical condition explained by explanatory variables (n=628)

			95% CI for odds	
	p value	Odds ratio	Lower	Upper
Radiation dose	0.006	1.012	1.003	1.020

Several studies found panoramic radiography equivalent to periapical radiographs in detecting apical periodontitis [15, 19–27]. Moreover, digital panoramic radiography reduces the radiation exposure with 50–80%. It is important to realise that the use of panoramic and periapical radiographs has its limitations. Both techniques have shown to underestimate the prevalence of apical periodontitis, since a minimum of bone loss is required [28, 29].

The high prevalence of caries and its rapid progression after radiotherapy of the head and neck region [30] suggest a high rate of pulpal involvement in the caries process and subsequent invasion of bacteria into the pulpal space. Moreover, an irradiated pulp becomes hypocellular and is therefore more sensitive to necrosis caused by uncontrolled caries [31]. Thus, one might expect an increase of apical periodontitis in irradiated patients.

In this study, we found that the prevalence of apical periodontitis was correlated to the radiation dose. Teeth with apical periodontitis also presented with a higher caries rate. The logistic regression analysis revealed the radiation dose as the only significant predictor of apical periodontitis. This implies that in areas of irradiated bone, the reaction of the bone tissue to bacterial infection is altered. It is believed that a radiation-induced-fibroatrophic process is the basis of bone damage post radiotherapy [32]. Different parts of this process are free-radical formation, endothelial dysfunction, inflammation, microvascular thrombosis, fibrosis and remodelling, and finally bone and tissue necrosis. According to Chrcanovic and colleagues [33], three distinct phases are seen in bone reaction to radiotherapy. In the third phase, disorganisation of the extracellular matrix and late fibroatrophy is seen with an inherent risk of late reactivated inflammation in the event of local injury. Earlier studies showed osteoclasts to be less radiosensitive than osteoblasts; thus, a relative increase in the lytic activity in bone may occur post radiotherapy [15, 34].

A chronic apical periodontal lesion consists of mononuclear and polymorphonuclear leukocytes and fibrovascular elements, all as a reaction on the invasion of bacteria or their by-products [35]. An explanation for the higher incidence of apical periodontitis in radiated bone could thus be caused by increased osteoclastic activity in response to bacterial invasion, responsible for local bone destruction, and hence the radiographic lesion, is disturbed due to the radiation of the bone. This theory is supported by our findings that suggest that bone with higher radiation doses is less likely to develop a radiographic detectable periapical lesion [13].

An extra factor interfering in the periapical inflammation process in irradiated patients are changes in composition of oral and root canal flora. Early studies on patients irradiated in the head and neck region describe a shift in the oral microflora after radiotherapy; more acidogenic and cariogenic microflora are present, whereas less anaerobic species occur [3, 4]. These changes commence 3 to 6 months after the start of radiotherapy and can last for up to 4 years [3, 4]. Endodontic periapical infections are mainly caused by anaerobic bacteria [36]. In an earlier study [18], we found the microflora present in the root canals of irradiated patients to be significantly richer than in non-irradiated control patients. Moreover, *Lactobacillus*, *Capnocytophaga*, *Actinomyces*, *Selenomonas*, and *Propionibacterium* spp. were present exclusively or more often after irradiation. The increased detection of these bacteria corresponds with the changes in the composition of the oral microflora after radiotherapy in the head and neck region. The exact effect of these bacterial changes in the root canal flora on the outcome of root canal therapy is unknown. A possible influence of these changes on the incidence and severity of periapical pathology cannot be excluded. Further research is needed on this topic.

Further research is also needed to clarify the exact mechanism of periapical inflammation post radiotherapy in relation to the composition of the root canal microflora and to the bone physiology.

Conflict of interest The authors declare that they have no conflict of interest.

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