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Post-radiation Dental Index: Development and Reliability

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Abstract

Goals of the work—To develop, validate, and assess the reliability of a clinical index for assessing post-radiation dentition breakdown.

Materials and methods—An expert panel of four dentists with expertise in post-radiation patient care, oral radiology and mineralized tissues reviewed a series of clinical photographs (n=60) depicting a wide range of post-radiation lesions varying in size, severity and location. Based on panel input related to lesion severity rankings and cut-points along a continuum of destruction, a semi-quantitative, ordinal lesion scale was developed. A companion scale was developed to account for existing restorations. The index was then reviewed by a separate panel of dental clinician/researchers for confirmation of face and content validity and was refined based on their input. Following index approval by the expert and confirmatory panels, the index was evaluated for test-retest reliability by two educator/clinicians. After a brief calibration session, examiners reviewed and independently scored a second series of lesion images (n=60). One week later, the same examiners independently scored the same images displayed in a different order. Inter and intra-rater reliability and agreement were assessed (Spearman r and Kappa statistic).

Main results—Respective to session 1 and 2, inter-rater reliability values were r=.97 and r=.98, with Kappa values of K=.93 and K=.95. Respective intra-rater reliability and agreement values were . 99 and .98 (rater 1), and .98 and .95 (rater 2).

Conclusions—A new index was developed and subsequently demonstrated face validity and excellent inter and intra-rater reliability for potentially evaluating the severity of post-radiation dentition breakdown.

Keywords

Post-radiation dental caries; post-radiation dental index; reliability; oral cancer

Introduction

The American Cancer Society and Oral Cancer Foundation estimate that approximately 35,000 new cases of oral cavity and oropharyngeal cancer are diagnosed in the U.S. annually with nearly 60% of those patients surviving for at least 5 years [1,2,25]. Even though head and neck radiotherapy will save the lives of many patients, the quality of life for these patients is

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drastically diminished due to numerous radiation-induced complications such as hyposalivation, severe debilitating destruction of tooth structure, and associated loss of masticatory function [4,20,21,23,30]. Although complete dentures might appear to be the answer to this problem, a removable prosthesis is not well-tolerated by irradiated oral mucosa. Patients tend to suffer from severe chronic denture irritations. With little or no saliva, there is a decreased adhesion between denture and tissue [5]. The current approach to dental care is to maintain as many healthy teeth as possible [6,26]; therefore, a better understanding of post-irradiation dental disease is necessary.

The post-radiation breakdown of the dentition tends to start within the first year following radiotherapy and becomes more severe with increasing time [30]. Post-radiation dental lesions differ considerably in clinical appearance, development and progression from dental caries in non-irradiated patients. Post-radiation lesions develop in a distinct manner with initial shear fracture of enamel followed by rapid decay of the exposed underlying dentin [17,18]. Post-radiation lesions tend to occur at the gingival margins, cusp tips, and incisal surfaces in contrast to typical caries, which develop in pits, fissures, and proximal areas. A brown-black discoloration of the tooth surface that occurs prior to surface breakdown is sometimes associated with teeth exposed to therapeutic radiation, again dissimilar from non-irradiated, carious teeth [15,20,30].

While the danger of developing ravaging dental destruction as a sequelae to head and neck radiation therapy has been well-documented, radiation-induced hyposalivation or xerostomia has to date been considered the only significant etiological factor [4,20,21,23,30]. However, anecdotal clinical observations suggest that post-radiation dental lesions tend to start earlier and be more severe in teeth within the radiation field. Thus, it has been proposed that the direct effect of therapeutic radiation on mineralized tooth structure along with xerostomia may be a significant causal factor [24]. To determine if there is a direct link between post-radiation lesions and factors such as radiation dose at the tooth level, tooth destruction/lesion severity must be accurately measured. Current measures of typical dental caries (DMFT and DMFS) are computed based on describing decayed, missing, or filled teeth or tooth surfaces. These indices are commonly used for epidemiologic field studies to assess the prevalence of dental disease and need for treatment [32]. Because post-radiation dental lesions develop and progress in a manner dissimilar from typical caries, traditional caries measures may not be valid for capturing the unique pattern and extent of tooth destruction seen in patients following therapeutic radiation. Therefore, this project was undertaken to develop, validate, and assess the reliability of a clinical index for assessing post-radiation dentition breakdown in order to determine whether there is a correlation between tooth destruction severity and tooth-level radiation dose.

Materials and methods

An expert panel comprised of four dentists with expertise in post-radiation patient care, oral radiology and mineralized tissues was convened to review existing criteria for measuring dental caries and identify factors important in assessing characteristics typical of dental destruction seen in the post-radiation patient population. The expert panel was then asked to review a series of clinical photographs depicting a wide range of post-radiation lesions that varied in size, severity and location. The images were made from teeth extracted from patients previously exposed to therapeutic radiation. Tooth collection procedures were approved by UMKC Adult Health Science IRB. In order to preserve the teeth for subsequent evaluation, oral surgeons treating the patients were informed as to the purpose of the study and used care to prevent forceps damage as the teeth were extracted.

The series of clinical photographs was compiled into two sets of 60 slides. The expert panel members first independently reviewed one of the two sets of images and characterized lesion severity with respect to appearance, defining attributes, and extent of tooth surface destruction. Panel members then discussed how the attributes collectively spread lesion severity along the continuum of destruction, and identified meaningful cut-points in severity ranking along this continuum. Once the group reached consensus on these rankings and cut points, a semi-quantitative, ordinal lesion scale was developed. Category descriptors for each scale point were drafted by the principal investigators and re-reviewed by the panel for content validity. The index was then reviewed by a separate panel of dental clinician/researchers for confirmation of face and content validity and subsequently refined based on their input. In addition, a companion scale was developed to account for existing restorations and potential associated repair over time. Based on input from the expert and confirmatory panels, the principal investigators developed the rubric for computing the mean surface score (MSS) and mean restoration score (MRS) for each tooth present in the mouth. The resultant post-radiation dental index scale incorporating separate scores for surface lesions (MSS) and restorations (MRS) and the directions for application are displayed in Figure 1.

In order to calculate the mean surface score for each tooth, the buccal, lingual and occlusal surfaces of posterior teeth, or buccal and lingual surface of anterior teeth are individually scored according to the 0–5 surface scale using a mouth mirror and direct light only. A tooth mean surface score is calculated as the sum of each tooth surface score divided by the number of evaluated surfaces (3 for posterior teeth and 2 for anterior teeth). Incisal surfaces on anterior teeth are not scored to avoid artificially inflating the tooth destruction score as a result of wear (attrition or abrasion). It is important to note that proximal surfaces are not scored to avoid the necessity of diagnostic radiographs for index use. This decision was discussed at length by the expert panel, and it was based on two factors: 1) current radiographs are often not available in this patient population; and 2) proximal lesions have not been considered a typical characteristic of post-radiation dental lesions [15,20,30]. A similar strategy is used to compute mean restoration scores (MRS).

Once the index was developed and approved by the expert and confirmatory panels, assessment of psychometric characteristics was undertaken. Specifically, surface score index stability (test-retest reliability) was assessed by two independent, well-experienced educator/clinicians who scored teeth with lesions on two separate occasions, separated by one week. The examiners were initially trained and calibrated on the surface score index. A few days later, the examiners independently scored the second set of coded lesion images (n=60) using the 0–5 surface score index (example lesions presented in Figure 2). One week later, the same examiners independently scored the same images; however, the order for the second display was randomized to reduce bias in scoring. Inter- and intra-rater reliability and agreement were assessed using Spearman rank order correlation coefficient and the Kappa statistic. In contrast to the surface score index which is based on the unique pattern of post-radiation tooth destruction, the restoration score index is based on the typical dental exam charting evaluation, i.e. how much of the tooth surface is restored and thus, was not included in the test-retest reliability.

Results

Representative photos of post-radiation lesions scored 1 through 5 during the surface score/lesion index reliability testing phase are displayed in Figure 2. Inter-rater reliability for the first and second rating sessions were $r = 0.97$ and $r = 0.98$, respectively. In order to control for chance agreement, the Kappa statistic was also computed with values of $K = 0.93$ and $K = 0.95$ for the first and second rating sessions, respectively. A similar high level of intra-rater reliability (test-retest) for the two examiners was determined for rater 1 ($r= 0.98$; $K = 0.99$) and rater 2

(r = 0.95; K = 0.95). Collectively, the surface score index was shown to have very high level of inter-and intra-rater reliability.

Discussion

Tooth destruction following therapeutic radiation is an important concern for treating cancer patients. To date, assessment of post-radiation tooth destruction has been relatively limited due to a lack of distinction between traditional dental caries and the unusual pattern of post radiation tooth destruction. In addition, no scales have been developed that accurately capture these patterns in a meaningful way. The primary purpose of this project was to develop a valid index and subsequently test the usability and stability of the index for assessing post-radiation tooth destruction. This study provides preliminary evidence that the scale has utility and meaningfulness for its intended use.

Given that dental caries and post-radiation tooth destruction have quite different characteristics of enamel and dentin loss, this scale may allow clinical researchers to capture the extent of destruction observed in the post-radiation patient population with higher validity. Although the proposed post-radiation dental index is primarily focused on capturing the severity of dentition breakdown via the surface score aspect of the index (MSS), the addition of the restoration score component (MRS) allows for the assessment of post-radiation lesions that might be restored over time.

Historically, post-radiation lesions were presumed to be associated with salivary gland damage and the resultant hyposalivation; thus, the saliva glands, the parotid gland in particular, are considered in any radiation-sparing treatment using intensity modulated radiation therapy (IMRT) with or without the cytoprotectant amifostine [16,19,27,28]. Despite the salivary gland protection techniques, most patients remain susceptible to post-radiation dentition breakdown. This could be related to a number of factors. For instance, IMRT techniques typically spare one or both of the parotid glands [8,12–14] without sparing the submandibular glands, which produce the majority of unstimulated saliva [7]. Moreover, amifostine might not be as efficacious for preventing xerostomia as initially reported [3,9,10,22,29,31] as indicated by a recent double-blinded, placebo-controlled phase III trial in which amifostine did not significantly reduce xerostomia [11]. Beyond these factors, the post-radiation tooth destruction might also be related to a potential direct link between tooth breakdown and radiation dose [24]. Currently, the developed index is being applied to a population of post-radiation patients to determine if cumulative tooth-level radiation dose is related to the severity of the post-radiation dental index score. In addition, the authors are currently evaluating the degree to which various scoring strategies and rubrics best capture the pattern of tooth surface destruction change over time. Because tooth surface destruction is cumulative, and restoration or extraction of teeth may confound interpretation of change over time, it is critical that validity and reliability of cumulative surface change over time be empirically evaluated.

Based on the results of the current study, the proposed post-radiation dental lesion index demonstrates the potential for assessing post-radiation dentition breakdown. Preliminary evidence suggests that the index, when used by experienced clinicians, has excellent inter-rater and intra-rater reliability and agreement in relation to assessing post-radiation dental lesion severity. However, it must be noted that these conclusions were based on viewing clinical photos of extracted teeth. As part of the current clinical study, we are evaluating the degree to which application of the index in a live patient population demonstrates similar consistency as that reported here.

In conclusion, the findings of this study provide encouraging indications about the validity and reproducibility of the post-radiation dental index. This would suggest the index will be

applicable for elucidating whether there is a correlation between tooth destruction severity and tooth-level radiation dose and potentially for measuring dentition breakdown over time.

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POST-RADIATION DENTAL INDEX **Subject number _____**

DIRECTIONS:

SCORE buccal, lingual and occlusal surfaces of the clinical crown for both unrestored tooth structure [Surface score (SS), 0-5] and any existing restorations [Restoration score (RS), 0-5 using appropriate rating scale. Sum SS and RS independently. Mean tooth SS or RS are obtained by dividing SS and RS by number of surfaces scored per tooth. Added info such as C(crown), P(Pontic), I(Implant), V(Veneer), O(Onlay), X(Missing tooth) placed in column next to tooth#.

Rad dose	Tooth / C,P,I,V,O,X		Buccal RS	Buccal SS	Occlusal RS	Occlusal SS	Lingual RS	Lingual SS	Total Tooth Restoration Score (TRS)	Total Tooth Surface Score (TSS)	Mean Tooth Restoration Score (MRS) =TRS/#S	Mean Tooth Surface Score (MSS)=TSS/#S
	1											
	2											
	3											
	4											
	5											
	6											
	7											
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	32											

When scoring unrestored surface or restoration, round up if in doubt.

Surface Score (SS) INDEX: 0, 1, 2, 3, 4 or 5

0 = No change in tooth surface. Appearance is shiny, smooth, & intact.
a. If surface is 100% restored, surface will also receive 0 SS.

1 = White line and/or brown stain. Enamel is intact and most of the surface is smooth and shiny.

2 = Single focal area of enamel/tooth structure loss (≤ 2mm diameter); surface may also have white line and/or brown stain.

3 = Single enamel/tooth structure loss focal area (>2mm diameter) OR more than 1 focal area of enamel/tooth structure loss: Total area of tooth structure loss <1/3 surface area

4 = Enamel/tooth structure loss ≥1/3 but <2/3 of surface area

5 = Extensive enamel/tooth structure loss ≥2/3 of surface area.

Restoration Score (RS) INDEX: 0, 1, 2, 3, 4 or 5

0 = No restoration

1 = ≤2mm X ≤2mm restoration

2 = >2mm X >2mm restoration but restored surface <1/3 surface area

3 = Restored surface ≥1/3 but < 2/3 surface area.

4 = Restored surface ≥2/3 but < 100% of surface area.

5 = Restored surface = 100% of surface area.

Figure 1.
Post-radiation dental index clinical research form.

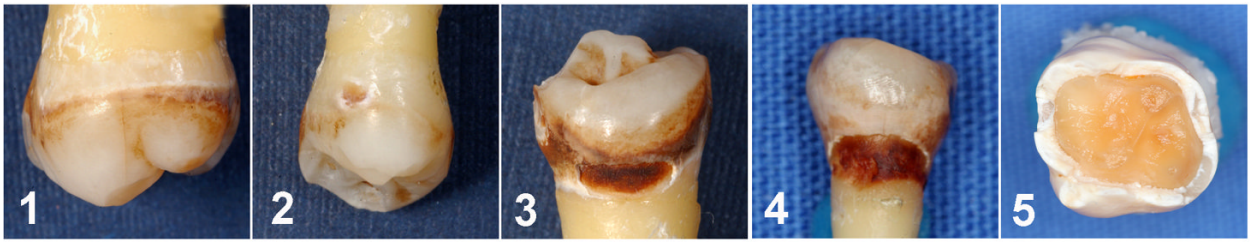

Figure 2.
Representative post-radiation surface lesions scored 1–5.