

ABSTRACT

Purpose: Describe the methodology used to construct tools for standardized data collection of head and neck cancer patients (HNCP).

Methods: We constructed the Oral Health Evaluation Tool (OHET) and Panoramic Radiograph Evaluation Tool (PRET) for systematic collection of long-term oral clinical/radiographical complications, prevalence, and severity. Tools were pilot-tested in 50 chemoradiation-treated HNCP >6 months post-therapy.

Results: Tools allowed for collection of extensive clinical and radiographical data. A medium of 1.9 years had elapsed since chemoradiation completion. Patients had a median of 6 missing teeth, 32.7% had no decay and a medium of 30% had filled surfaces; 42.9% had moderate-to-severe decay. Reduced/thickened saliva was noted in 85.4% and dry mucosa in 93.9%. Gingival bleeding was present in 75.5% HNCP and attachment loss in 86%. Four patients had trismus.

Conclusions: Tools were user friendly and provided comprehensive, reproducible, and inexpensive means to evaluate post-therapy oral health of HNCP. Validation testing is ongoing.

KEY WORDS: oral health outcomes, head and neck cancer, tool development, oral health evaluation, panoramic radiograph evaluation

Development of tools for the oral health and panoramic radiograph evaluation of head and neck cancer patients: A methodological study

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Introduction

Concurrent chemoradiation (CCR) is frequently used in treatment of locally advanced head and neck cancer (HNC). CCR can injure mucous membranes¹ and underlying soft tissues.² HNC patients (HNCP) experience a variety of adverse oral health outcomes (OHOs) including xerostomia/fibrosis, trismus, infection, tooth damage, periodontal disease and osteoradionecrosis. Surgery and radiation can compromise oral function.³⁻⁷ Prevention and monitoring can decrease symptom burden and improve function and quality of life (QOL). There is a paucity of validated tools to evaluate oral health needs of HNCP.⁸ The Oral Care Study Group of the Multinational Association of Supportive Care in Cancer/International Society of Oral Oncology (MASCC/ISOO) concluded that large, multicenter studies are required to define incidence, prevalence, severity, and impact of oral complications of cancer therapy.^{9,10} They recommended use of clearly defined oral outcomes for future studies, however could not make specific measurement tool recommendations.⁹ Primary outcome for OHO assessment is dental integrity, commonly measured using the Decayed, Missing, Filled Teeth/Surfaces (DMFT/S) index.^{11,12} Limitations to DMFT/S include failure to capture decay between posterior teeth, dental demineralization, no data on reason for missing teeth, no composite/resin restorations and lack of denominator.¹³ Normative DMFT/S data are categorized according to age; however applicability to HNCP and utility of age-matched controls are unknown.

Nyvad introduced diagnostic criteria taking into account the dynamic nature of dental caries.¹⁴ Using tactile and visual

criteria, lesions were divided into active and inactive.^{14,15} The International Caries Detection and Assessment System

Table 1. Existing caries assessment and evaluation tools.

Nyvad 1999 ¹⁴	Nyvad 2003 ¹⁵	ICDAS-I ¹⁶ 2004	ICDAS-II ⁴⁴ Bogota 2008 Consensus
Tooth surface: 0 = sound; 1 = active (intact); 2 = active (surface discontinuity); 3 = active (cavity); 4 = inactive (intact); 5 = inactive (surface discontinuity); 6 = inactive (cavity); 7 = filling; 8 = filling with active caries; 9 = filling with inactive caries	Tooth surface: 0 = sound; 1 = ANC lesion; 2 = INC lesion; 3 = cavity (cavity, filling, or extracted)	Tooth surface: (codes 0–9)-Sound - Sealed: full/partial - Restored: tooth-colored/ amalgam/lost or broken/temporary - Crowned - Missing - Carious status:0 = sound; 1 = pits/fissures; 2 = smooth; 3 = distinct visual change; 4 = localized enamel breakdown; 5 = underlying dentin shadow; 6 = distinct cavity; 7 = extensive cavitation-Did not include activity assessment at tooth surface level - Divided into sections covering coronal caries, root caries and caries-associated-with-restorations-and-sealants (CARS) - All conditions specified in criteria, for example, cleaning and drying of tooth surfaces	- Histology (0-6): enamel/dentine demineralization - Visual appearance 0 = sound; 1 = 1st visual change in enamel; 2 = distinct visual change in enamel; 3 = localized enamel breakdown; 4 = underlying dentin shadow; 5 = distinct cavity within visible dentin; 6 = extensive cavity with visible dentin-Activity assessment (active or arrested) - Radiographical classification of radiolucency (0–6) - Clinically cavitated - LESION detection aids - Scores of FOTI (0–6) - Scores for ECM (0–6) - Care planning aids: - Risk assessment - PTO or OTO - Progressing, arrested, regressing
Combination visual and tactile criteria	Combination visual and tactile criteria	Combination visual and tactile criteria	Combination visual and tactile criteria
Kappa Intraexaminer examinations: 0.74–0.85	Not reported	Kappa: 1st wave I: intraexaminer (4 examiners): 0.83–0.98 2nd wave I: between 2 main examiners: 0.78–0.82 2nd wave I: between other examiners: 0.59–0.79 1st wave II: 0.81–0.95 2nd wave II: 0.73–0.78	
Kappa interexaminer examinations: 0.78–0.80	Not reported	Kappa: interexaminer: 0.59–0.82 1st wave I: between the 2 main examiners: 0.73 1st wave I: between other examiners: 0.78–0.90 2nd wave I: 0.63–0.75 1st wave II: 0.90–0.95 2nd wave II: 0.68–0.76	
ICDAS = International Caries Detection and Assessment System; ANC = active noncavitated; INC = inactive noncavitated; FOTI = fiber-optic translumination; ECM = electrical conductance measurements; PTO = preventative treatment option; OTO = operative treatment option.			

(ICDAS) core criteria were developed for use on enamel and dentine caries adjacent to restorations and sealants, and on coronal/root surfaces.¹⁶ Readers are referred to “The ICDAS: an integrated system for measuring dental caries” for tool development information.¹⁶ The goal of these and later criteria was to standardize comparison with a unifying system (Table 1).^{17,18}

Panoramic radiography is a rapid, convenient, and simple method to display patient’s general dental condition on a single film. It screens jaw areas not covered by intraoral dental radiographs, and

projects normal anatomic relationships.^{19–21} While inherent distortions and magnifications exist, the image provides broad coverage including maxilla, mandible, zygomatic arches, and temporomandibular joint (TMJ).^{21,22} Panoramic radiography provides meaningful “negative information” (e.g., lack of intraosseous pathological conditions).²² Images can help patients understand their dental needs.²² Panoramic radiography can be used in intractable patients.²² Research tools capturing data from panoramic studies have not been validated in HNCP and are not widely used.

Based on the need for research tools to measure OHO in HNCP, we undertook development of Oral Health Evaluation Tool (OHET) and Panoramic Radiograph Evaluation Tool (PRET). We report the methodology used in the development and early testing of these tools.

Materials and methods

Part 1: Tool development

The oral health evaluation tool
 Upon review of prior tools, a panel including dentists and oncologists, who

care for HNCP, devised a new, comprehensive tool. OHET was developed as a systematic assessment of dental health with emphasis on OHO common to HNCP. OHET included: (1) assessment time point; (2) number of remaining teeth; descriptive data regarding DMFT/S; (3) visual examination of all teeth surfaces applying ICDAS-II criteria (codes: 0 to 6; Table 1)¹⁸; (4) tactile examination using an explorer commenting on enamel and dentin surfaces (smooth enamel = superficial defects if open and with borders smooth to probing; rough enamel = surfaces affected by caries, not due to staining, mineralized debris, or calculus. Number of surfaces affected was noted. Dentin was scored as hard or rough/soft to probing. The latter included irregular breakdown detected with standard dental explorer); (5) salivary examination and salivary flow measurement; (6) interincisal opening (IIO) measurement; (7) gingival and periodontal status; (8) dentures issues (if applicable); and (9) documentation of oral health findings requiring treatment including infection. OHET includes a three-step procedure for caries diagnosis as described by Ekstrand: (1) caries detection, (2) lesion severity, and (3) lesion activity (visual appearance, location and tactile: rough/soft or smooth/hard).²³ One study dentist (JR) performed all clinical examinations. A dental assistant recorded notes for JR during the examination and weighed saliva samples (Figure 1).

The panoramic radiograph evaluation tool

Based on a literature review and expert opinion (two dental oncologists, two dental radiologists, two medical oncologists, and two experienced general dentists), we developed PRET encompassing all clinically significant OHO assessable by panoramic radiography. PRET components are listed in Figure 2. A panoramic X-ray unit (GE Orthopantomograph OP100D, Instrumentarium Corporation Imaging Division, GE Healthcare, Tuusula, Finland) was used for all exposures (Model THA100; Serial Number: 16310). Panoramic radiographs were digital,

developed by automatic processing, reviewed on computer screen and independently scored using PRET by JR, and two oral oncologists blinded to oral exam findings. Comparisons were made between the three reviewers' scores. Scores were deemed in "agreement" if reviewers recorded the same answer and "disagreement" if answers were discrepant. Discrepant scores were reviewed to determine whether discrepancy was due to tool design or content. Depending on the item, discrepancies could be based on a single patient (e.g., ORN), a single tooth (e.g., impaction), or single quadrant (e.g., periodontal bone loss). Several items required clarification and/or standardization through definition of parameters. Some items described abnormalities that were not easily or consistently evaluated on panoramic radiograph and were deleted.

Part 2: Preliminary testing

Methods

The study enrolled 50 patients with history of HNC status postprimary or adjuvant chemoradiation. Patients were recruited from the Henry Joyce Outpatient Cancer Clinic of Vanderbilt-Ingram Cancer Center between May 2011 and April 2012. Enrollment criteria included: ≥18 years old, English-speaker, provide written informed consent. Patients completed a demographic survey. Study staff completed a disease treatment summary form. Patients underwent a dental evaluation, conducted by JR. Patients with urgent/emergent dental issues were directed to their primary dentist for care. Patients without dental insurance were referred for indigent care. The Scientific Review Committee and the Institutional Review Board approved the study. All patients signed informed consent.

Additional study measures

Demographic survey. Recorded general epidemiologic data included gender, age, race, ethnicity, marital status, highest grade of education, work status, household income, insurance status, transportation access, alcohol, and tobacco use.

Disease and treatment form. Disease and treatment form included date of diagnosis, stage, primary site, pathology, date and type of surgery, beginning and end dates of chemoradiotherapy. Comorbidities and medications were not included.

Salivary flow measurement. Unstimulated and stimulated salivary flow rates (reported in milligrams per minute) were measured as described by Sreebny and Valdin.²⁴ Sialometry was performed between 8:12 am and 3:28 pm. Patients were asked to abstain from eating, drinking, or brushing their teeth for >1 hour prior to testing. Patients passively emptied saliva into a pre-weighed collecting cylinder for 3 minutes. After a rest period of 3 minutes, stimulated salivary production was collected while patients chewed flavorless utility wax for 3 minutes. Whole saliva sialometry was chosen over parotid measurements as a more practical and reliable method.²⁵

IIO distance. IIO measurement was recorded in millimeters.²⁶ For patients with edentulous mandible or maxilla, not wearing dentures, the distance between incisal edge of the right central incisor and alveolar ridge (in the opposing right central incisor position) was measured. One patient edentulous in maxilla and mandible who was not wearing dentures was excluded from measurement as accurate site could not be determined.²⁶

Data analysis

All data analyses were conducted using SPSS® Version 22. Frequency distributions (counts and %) were used to summarize nominal and ordinal data from this study. Due to the skewed nature of the continuous data, median, interquartile range (IQR), minimum, and maximum values summarized those distributions. The IQR used was bounded by the 25th and 75th percentile values thus defining the middle 50% of values.

Results

Patient characteristics

Patients (N = 50) were predominantly white, married males, 20% completed 12th

ORAL HEALTH AND PANORAMIC RADIOGRAPH EVALUATION TOOLS

Patient Name: _____ Date: ___/___/___
 Study Number: _____ Gender: Male / Female

Assessment Time Point: Pretreatment / ___ months post treatment

Total # remaining teeth: _____

Dental Status: Decayed Missing Filled Surfaces (Number):
 Decayed Surfaces: ___ Missing Teeth: ___ Filled Surfaces: ___

ICDAS-II Criteria:
 Visual Examination:

Code	# Surfaces	Descriptor
0		Sound tooth surface: no evidence of caries after prolonged drying
1		First visual change: opacity or discoloration (white or brown) after prolonged air drying or hardly seen on a wet surface
2		Distinct visual change: opacity or discoloration distinctly visible when wet, still visible after drying
3		Localized enamel breakdown due to caries with no visible dentine or underlying shadow; opacity or discoloration when wet and after air drying
4		Underlying dark shadow from dentine +/- localized enamel breakdown
5		Distinct cavity with visible dentine; visual evidence of demineralization and dentine exposed
6		Extensive distinct cavity with visible dentine and more than half of the surface involved

Clinical signs characterizing decay possibly associated with RT:
 (check ALL that apply)

- demineralization of enamel surfaces next to the gum line
- brown stain of surfaces next to the gum line
- demineralization of incisal edges/cusp tips
- demineralization of buccal and lingual enamel surfaces
- brown stain of incisal edges/cusp tips
- breakdown (roughness, cavitation) of surfaces next to the gum line
- breakdown (roughness, cavitation) of incisal edges/cusp tips
- fracture of crowns at the gum line
- other: please describe _____

Mucosal lesions:
 Check all that apply:

- Ulceration
- Red lesion (example: erythroplakia)
- White lesions (example: leukoplakia)
- Exposed bone (osteonecrosis)

Comment: _____

Dental Tactile Examination:

Use a dental explorer with gentle pressure on all but occlusal surfaces; hold the explorer tip at an angle to the dental surface and move along the surface to assess for changes in surface textures and softness without force applied at 90 degrees to the surface examined so that penetration of the explorer tip into altered tooth structure is limited.

Enamel: # surfaces: 0: ___ 1: ___
 0 = smooth to probing; superficial defects accepted if open and the borders are smooth to probing; roughness accepted if due to staining/mineralized debris/calculus
 1 = rough due to caries and not due to staining/partly mineralized debris/calculus/anatomy

Dentin: # surfaces: 0: ___ 1: ___
 0 = Dentin is hard to probing
 1 = rough/soft to probing and/or an irregular breakdown detected with ball-ended probe

Percussion Tenderness: Yes
 No

Comment: _____

Gingival and Periodontal status:

Please place a check mark in the appropriate column

	None	Visible Plaque <1/2 tooth	Visible Plaque >1/2 tooth
Right Maxilla			
Maxillary anterior			
Left Maxilla			
Right Mandible			
Mandibular anterior			
Left Mandible			

Visible plaque: 0=none, 1=visible plaque <1/2 of tooth; 2 visible plaque > 1/2 of tooth
 Sextent:
 R Maxilla: ___ Maxillary Anterior ___ L Maxilla ___
 R Mandible ___ Mandibular Anterior ___ L Mandible ___

Please place a check mark in the column if gingival erythema or bleeding is present

	Right Maxilla	Maxillary Anterior	Left Maxilla	Right Mandible	Mandibular Anterior	Left Mandible
Gingival erythema present						
Gingival bleeding present						

Gingival erythema: no=0, yes=1
 Sextent:
 R Maxilla: ___ Maxillary Anterior ___ L Maxilla ___
 R Mandible ___ Mandibular Anterior ___ L Mandible ___

Gingival bleeding: (0, 1): Bleeding: no=0, yes=1
 Sextent:
 R Maxilla: ___ Maxillary Anterior ___ L Maxilla ___
 R Mandible ___ Mandibular Anterior ___ L Mandible ___

Please place a check mark in the appropriate columns

	None	CEJ Exposed	Root Exposed
Right Maxilla			
Maxillary anterior			
Left Maxilla			
Right Mandible			
Mandibular anterior			
Left Mandible			

Attachment loss: 0=none visible, 1=CEJ exposed, 2=root exposed
 Sextent:
 R Maxilla: ___ Maxillary Anterior ___ L Maxilla ___
 R Mandible ___ Mandibular Anterior ___ L Mandible ___

Tooth mobility:

Is there tooth mobility?: none
 mild (1mm - 2mm)
 severe (≥ 3mm)

teeth with MILD mobility: _____ teeth
 # teeth with SEVERE mobility: _____ teeth

Active Infection: Yes
 No
 Please specify: Bacterial / Fungal / Viral

Describe details regarding infection (location, pathogen if known): _____

Trouble with dentures:
 Retention: ___ adequate, ___ not adequate
 Stability of prosthesis with eating: ___ adequate, ___ not adequate
 Need for denture adhesive: ___ yes ___ no
 Ease of insertion: ___ good, ___ difficult, ___ impossible
 Sores associated with denture: ___ yes ___ no
 Unable to use: ___ yes ___ no

Trismus measure:
 If the patient has either an edentulous mandible or maxilla and is not wearing dentures, the distance between the incisal edge of the right central incisor and the alveolar ridge (in the position of the opposing right central incisor) is measured.
 _____ mm

Oral health findings requiring treatment: Circle all that apply. Comments may be added

- Denture adjustment/reline/repair/new denture
- Prophylaxis (supra-gingival plaque removal and polishing)
- Periodontal scaling and root planning
- Periodontal surgery: Nature of surgery and site: _____
- Dental restoration: Specify tooth #: _____
- Endodontics: Specify tooth #: _____
- Dental extraction: Specify tooth #: _____
- Mucosal lesion: Specify: _____
- Infection: bacterial/fungal/viral
- Pain (dental, mucosal): _____
- Trismus management
- Saliva management

Treatment/referral need (specify for each condition):
 Routine
 Urgent

Definitions:
Routine care or intervention: can occur in greater than 3 months without harmful consequence
 Examples: - Caries not reaching the pulp cavity
 - Teeth with > 2/3 bone support

Urgent or Emergent need: intervention needed immediately or within weeks
 Examples: - Caries in dental pulp cavity
 - Teeth with < 1/3 bone support
 - Pathologies (cyst and tumor)
 - Severe TMJ DJD (loss of vertical condular height)
 - Osteonecrosis

Figure 1. Oral health evaluation tool.

ORAL HEALTH AND PANORAMIC RADIOGRAPH EVALUATION TOOLS

Participant ID: _____
 Patient Image Identifier: p (e.g.: p01, p02): _____
 Start time of form: _____
 Date Panoramic radiograph Taken: _____

1. **Quality of panoramic:** acceptable not acceptable

-Acceptable includes:
 -no distortion or acceptable distortion
 -no artifacts, good contrast and density
 -artifacts/contrast/density no decreasing diagnosis
 -obscuring of anterior sextants due to overlap from spine

-Not acceptable includes:
 -non-acceptable distortion
 -artifacts/contrast/density decreasing diagnosis

2. **Number of teeth:** _____ (number from 0-32)

3. **Impacted teeth:** select ALL tooth numbers that apply:
 None, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, not visible due to quality of radiograph

For each impacted tooth:
 Tooth # _____: Degree of impaction: Full bone impaction
 Partial bony impaction
 Soft tissue impaction
 At risk for no direct oral access to coronal space

Does the impacted tooth affect the adjacent tooth: Yes No

4. **Caries threatening the pulp:** select ALL tooth numbers that apply
 None, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, not visible due to quality of radiograph

5. **Caries into the pulp:** select ALL tooth numbers that apply
 None, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, not visible due to quality of radiograph

6. **Fractured tooth/filling:** select ALL tooth numbers that apply
 None, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, not visible due to quality of radiograph

Do any of the dental fractures involve the pulp: Yes No

7. **Retained root:** select ALL tooth numbers that apply
 None, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, not visible due to quality of radiograph

8. **Past Endodontics:** select ALL tooth numbers that apply
 None, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, not visible due to quality of radiograph

9. **Radiolucent lesion:** select ALL tooth numbers that apply
 None, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, not visible due to quality of radiograph

Tooth # _____: Radiolucent lesion:
 select ALL descriptors that apply: periapical
 Not periapical
 Cyst-like
 Tumor-like
 Other: specify _____

10. **Radio-opaque lesion:** select ALL tooth numbers that apply
 None, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, not visible due to quality of radiograph

Tooth # _____: Radio-opaque tooth: comment: _____

11. **Is there any area of severe bone loss:** Yes No
 Not visible due to quality of radiograph

-Severe periodontal bone loss
 -teeth with $\leq 1/3$ bone support

-Not severe periodontal bone loss
 -teeth with $>2/3$ bone support

If there is SEVERE bone loss, please identify which quadrants are affected:
 Select ALL that apply: Right Upper Quadrant
 Left Upper Quadrant
 Right Lower Quadrant
 Left Lower Quadrant

12. **Irregular bone changes suspicious for osteoradionecrosis:**
 Yes: comment _____
 No
 Not visible due to quality of radiograph

13. **Jaw Fracture:** yes No

14. **Opacification(s) in maxillary sinus:** yes No

15. **Masses in the oral tissue:** yes No

16. **Temporomandibular joint (TMJ) and Degenerative joint disorder (DJD):**
 TMJ or DJD present
 None
 Not visible due to quality of radiograph

-Presence of TMJ includes:
 -Loss of vertical condular height
 -Visible radiolucency, osteophyte, flattening of condyle or glenoid fossa

17. **Radiographic evidence of atheromas** (calcification of the carotid artery: Yes No

18. **Dental Care needs:** Routine
 Urgent Intervention required

Routine:
 Defn: routine care or intervention that can occur in greater than 3 months without harmful consequences:
 -caries not reaching the pulp cavity
 -teeth with $>2/3$ bone support
 -TMJ/DJD: none
 -impacted teeth not affecting adjacent teeth
 -dental fracture not involving the pulp
 -retained root

Urgent:
 Defn: urgent or emergent needs: intervention needed immediately or within weeks
 -caries into dental pulp cavity
 -teeth with $\leq 1/3$ bone support
 -dental and/or root resorption
 -dental fracture involving the pulp
 -periapical radiolucencies
 -pathologies (cyst and tumor)
 -severe TMJ and DJD (loss of vertical condular height)
 -jaw fracture
 -masses in oral tissues
 -opacification in maxillary sinus believed to be malignancy or symptomatic infection
 -oral ulceration
 -osteoradionecrosis
 -impacted teeth affecting adjacent tooth

Other issues: please specify: _____

Time form is completed: _____

Figure 2. Panoramic radiograph evaluation tool.

Table 2. Demographic and treatment history.

Age, years	
Median	58
25–75th interquartile range	52–63
Range (min, max)	37, 72
Sex, no. (%)	
Female	11 (22)
Male	39 (78)
Education, no (%)	
Completed 10–11th grade	3 (6)
Completed 12th grade	10 (20)
Post high-school education	37 (74)
Race, no (%)	
African American	2 (4)
White	48 (96)
Household income, no (%)	
<\$10,000	2 (4)
\$10–20,000	4 (8)
\$20–40,000	9 (18)
\$40–60,000	8 (16)
>\$60,000	19 (38)
Prefer not to respond	8 (16)
Type of treatment, no (%)	
Induction	1 (2)
Combined chemoradiation	46 (92)
Unknown	3 (6)
Time since radiation completed, years	
Median	1.87
25–75th interquartile range	1.07–3.80
Range	0.2–19.9
Primary site, no (%)	
Oral cavity	4 (8)
Nasopharynx	3 (6)
Oropharynx	28 (56)
Larynx	3 (6)
Hypopharynx	1 (2)
Salivary gland	2 (4)
Nasal cavity and paranasal sinuses	3 (6)
Other/unknown primary	6 (12)
Tobacco Use, no (%)	
Never smokers	20 (40)
Prior/current smokers	30 (60)

grade and 66% had posthigh-school education. Median age was 58 years (range, 37 to 72). Of those for whom data were available, a median time of 1.9 years had elapsed since completion of chemotherapy (N = 48, min = 0.5, max = 9.8) and radiation (N = 48, min = 0.1, max = 19.9). Eighty-seven percent of patients had squamous cell carcinoma histology and 56% were oropharyngeal primaries (Table 2).

Oral health evaluation tool

Tool characteristics

Dentist (JR) found OHET easy to use. Standard examination took approximately 30 minutes, with more complex evaluations of decay with patient education requiring approximately 90 minutes.

Preliminary results

Dental care history: All study patients had their dental health evaluated and stabilized (including extractions) prior to radiation initiation. Patients received educational material regarding proper dental care in radiated patients as per MASCC/ISOO guidelines, including routine use of fluoride (topical application using a 1.1% sodium fluoride gel with a tray, toothpaste or a rinse daily).

Decayed-missing-filled teeth: Patients had a median six teeth missing (IQR: 4 to 12, min = 2, max = 32). Median number of dental surfaces was 130 (IQR: 100 to 140). One patient had no teeth (thus, 0 available dental surfaces) and was excluded from decayed and filled tooth/surface analyses. One patient had 150 surfaces available. Based on DMFT/S, the median percentage of available surfaces decayed was 2.14. Sixteen of 49 patients (32.7%) had no decay, 20 (40.8%) had ≤10% decayed surfaces, 3 (6.1%) had 11% to 20% decayed surfaces, 6 (12.2%) had 21% to 30% decayed surfaces, 3 people had 39% to 41% decay of available surfaces, and 1 had 100% decay surfaces. A median of 30% of available surfaces per patient were filled (IQR: 18 to 39, range, 2 to 100). On visual examination according to ICDAS-II criteria, 30 (61.2%) of the 49 patients with teeth had distinct visual changes (code 2) on enamel surfaces.

Table 3. Oral Health issues requiring treatment.

Oral health intervention (N = 50)	No. patients requiring intervention (%)
Denture adjustment/reline/repair/new denture	5 (10)
Dental cleaning: prophylaxis, scaling, root planning	44 (88)
Periodontal surgery	3 (6)
Dental restoration	30 (60)
Endodontics	12 (24)
Dental extraction	13 (26)
Mucosal lesion	1 (2)
Infection	5 (10)
Dental pain	3 (6)
Mucosal pain	2 (4)
Trismus management	6 (12)
Saliva management	38 (76)

Cavities: A clinically significant percentage of patients (21 of 49, 42.9%) had moderate-to-severe disease with either distinct cavity (code 5) or extensive distinct cavity (code 6). Of the 16 patients with distinct cavity (code 5), 14 had 11% or less surfaces involved, 1 had 24% and another had 40% of available surfaces involved. Of the 11 patients with extensive distinct cavities (code 6), 6 patients had <10% of surfaces with extensive cavities, 4 had 10% to 40% surfaces involved and 1 had all surfaces with extensive decay. Among the 49 patients with available surfaces, a median 0.74% of surfaces were rough (IQR: 0% to 5%, min = 0, max = 87%).

Salivary assessment by clinician-reported outcome (Observational end-points): Salivary examination revealed 75.5% (37 of 50 patients) with no saliva in the floor of mouth. Reduced or thickened saliva was noted in 85.4% (41 of 49 patients, 1 patient missing data). No mucosal wetting (dry mucosa) was seen in 93.9.0% (46 of 49) of patients.

Sialometry data using preweighed collecting cylinders is not reported as this methodology has been previously established and validated.²⁴

Gingival and periodontal health: Gingival erythema and attachment loss was evaluated based on site (right/left

maxilla and mandible, maxillary and mandibular anterior). Erythema involving at least one site was present in 75.5% of patients with teeth (37 of 49). Gingival bleeding evaluated in the same areas was present in 73.5% of those patients (36 of 49). Furthermore, 65.3% (32 of 49) had mild visible plaque (<1/2 tooth), while 22.4% (11 of 49) had severe plaque (≥1/2 tooth with visible plaque). Attachment loss was observed in approximately 86% of patients (42 of 49) with teeth. Cementoenamel junction (CEJ) was exposed in 32.7% (16 of 49), and root exposure was noted in 53.1% (26 of 49).

Trismus: Severe trismus (≤25 mm) was found in four patients (8.7%). Moderate trismus (26 to 29 mm) noted for 1 patient (2.2%). Mild trismus (30 to 39 mm) was present in 10 patients (21.8%). The remaining 31 patients had no trismus according to IIO (67.2%).

Oral health interventions: There were insufficient numbers of patients with dentures to conduct meaningful subsample analysis. Oral health issues requiring treatment are listed in Table 3. Panel discussion following analysis of results resulted in addition of the following items to revised PRET: Clinical signs characterized decay possibly associated with radiotherapy, oral mucosal lesions, percussion tenderness of teeth, tooth

mobility, and active infection specification (bacterial/fungal/viral).

Panoramic radiograph

The original 50 panoramic images were reviewed by two board certified dental radiologists using the modified PRET. Based on results of the second review, the expert panel (two physicians, three dentists, two oral radiologists, and one biostatistician) reviewed items with >10% disagreement and made final modifications to PRET. Of the 20 original questions, 12 had high concordance (>97% agreement) and were retained in unmodified format. Three items were deleted, one was added and five items were modified.

Two questions were excluded for high levels of disagreement or redundancy: “irregular mucosal thickening/mass in the antrum”—66% disagreement and “mucous retention in antrum”—28% disagreement. This was felt to be better addressed by “opacification(s) of maxillary sinus” which was retained. Oral ulceration was removed because it was felt evaluable only by clinical examination. For clinical relevance, “quality of panoramic” was revised from “good/fair/poor” to “acceptable/not acceptable.” Acceptable qualities included no distortion or acceptable distortion; no artifacts, good contrast and density; artifacts/contrast/density no decreasing diagnosis and/or obscuring of anterior sextants due to overlap from spine. Panoramic radiographs deemed not acceptable included nonacceptable distortion and artifacts/contrast/density decreasing diagnosis.

“Periodontal bone loss” was described as “severe/not severe/edentulous” had 64.8% disagreement. Discordance likely rests in the limitation of panoramic radiographs to describe only extreme bone loss. The periodontal bone loss descriptor was changed to “severe (teeth with ≤1/3 bone support) or not severe (teeth with >2/3 bone support).” TMJ and degenerative joint disorder (DJD) when rated as “severe/not severe/none/not visible” had 48% disagreement. The question was changed to presence or absence of TMJ/DJD, or not visible due to quality of radiograph. The

Table 4. Panoramic radiograph summaries.

	Both reviewers, min–max	Both reviewers if present, min–max
Total teeth	0–30	
	Both reviewers presence of any, N (%) min–max	Both reviewers If present, # min–max
Impacted teeth	4 (8.0)	1–2
Caries threatening pulp	11 (22.0)–21 (42.0)	0–8
Caries into the pulp	7 (14.0)–17 (34.0)	0–8
Fractured teeth	7 (14.0)–13 (26.0)	0–8
Teeth with retained root	5 (10.0)–7 (14.0)	1–3
Teeth with endodontics	23 (46.0)–25 (50.0)	1–7
Teeth with radiolucencies	12 (48.0)–13 (56.5)	0–7
Teeth with radioopaque lesions	6 (12.0)–16 (32.0)	0–3
Bone Loss	14 (28.0)–50 (100.0)	1–4 ^a
^a #quadrants.		

supplied definition of TMJ is “loss of vertical condylar height and visible radiolucency, osteophyte, flattening of condyle or glenoid fossa.” Dental care was needed when graded as “routine/urgent/emergent” had 30% disagreement, categorization was simplified to the clinically actionable designation: “routine or urgent intervention required.” Criteria definitions are included on PRET. If “urgent care” needs are identified, the computerized version of the form prompts the reviewer to confirm the designation. Routine care/intervention is defined as: can occur in >3 months without harmful consequence. Clinical scenarios include caries not reaching dental pulp; teeth with >2/3 bone support; no TMJ/DJD; impacted teeth not affecting adjacent teeth; dental fracture not involving pulp; retained root. “Urgent intervention” needs to be acted upon immediately or within weeks. Findings include caries in dental pulp, teeth with <1/3 bone support; dental and/or root resorption; dental fracture involving pulp; periapical radiolucencies; pathologies (cyst, tumor); severe TMJ/DJD (loss of vertical condylar height); jaw fracture; masses in oral tissues; opacification in maxillary sinus believed to be malignancy or active infection;

osteoradionecrosis and impacted teeth affecting adjacent tooth (Table 4)

For completeness, we added two questions: whether dental care preradiotherapy was provided, and radiographic evidence of atheromas (calcification of carotid artery) (Figure 2).

Discussion

OHET/PRET provides a comprehensive evaluation for use in clinical trials, clinical databases and routine dental care. OHET incorporates DMFT/S, a visual examination, mucosal lesion evaluation, dental tactile examination, salivary examination, gingival and periodontal status evaluation, tooth mobility, active infection evaluation, trismus and denture issues by a trained oral health provider. Certain pathologies are more easily identified by panoramic radiograph, including impacted teeth, retained root, past endodontics, radiolucent and radioopaque lesions, tumor-involving bone, osteoradionecrosis, jaw fracture, maxillary sinus opacifications, TMJ/DJD, and radiographic evidence of carotid artery atheroma. OHET/PRET provides comprehensive and complimentary data regarding oral health status of HNCP posttreatment. Certain pathologies may

require oral assessment and radiographic imaging for meaningful evaluation, including caries threatening and into the pulp, dental abscess, periodontal bone loss and tumor in bone, jaw fracture, and osteoradionecrosis. Fractured teeth and masses in oral tissue were included in PRET, but in practice are primarily assessed during oral evaluation.

Ideally, imaging studies (1) provide a comprehensive objective measure of oral health status and (2) be amenable to central review thus eliminating the issue of inter-rater reliability. Our data confirms that panoramic radiograph alone is insufficient to assess oral health status. For example, panoramic radiography was inadequate to assess caries status and periodontal disease.²⁷ Panoramic radiography is not intended as a substitute for periapical/bitewing images and/or clinical evaluation, but remains a valuable oral examination adjunct.²¹ Literature supports a combination method of caries evaluation along the continuum of the caries process and lesion activity.²⁸

Our data showed high rates of dental disease including caries, retained root fragments, impacted teeth, periodontal disease, hyposalivation, and trismus. Recognition of caries is critically important due to potential need for treatment and because current caries status predicts future caries activity.²⁹ Noncavitated carious lesions have the potential to regress with early intervention, with marked improvement in likelihood if oral hygiene is maintained and fluoride/remineralizing treatments are initiated.^{15,30} Active lesions require intervention.¹⁵ Methods developed for this report appear to adequately identify caries. Our data on caries prevalence are similar to the published MASCC/ISOO review. In our study, visual examination yielded 23.91% with distinct cavities and 10.87% with extensive cavities; MASCC/ISOO systematic review found 21% to 24% prevalence of dental caries.¹⁰ Patients in our study had stabilization of dentition prior radiotherapy initiation, confirming the rapid development of dental disease in HNCP.

Prior studies showed retained root fragments in 12.3% to 15.3% of asymptomatic edentulous patients.^{19,31} Our study

demonstrated 10% to 14% of patients having retained roots on panoramic radiography, despite dental treatment prior to cancer therapy. Patients had between one and three retained roots. In the general population, completely impacted, asymptomatic teeth without radiographic evidence of resorption or enlarged follicle are often left *in situ*; radiolucent regions would prompt root removal.¹⁹ In HNCP special consideration must be paid to these teeth as postradiation removal carries a risk of jaw osteoradionecrosis. Impacted teeth, most commonly maxillary canines and third molars have been noted in 6.2% of edentulous patients.³¹ Panoramic radiography in our study documented 8% of patients having impacted teeth, with 1 to 2 impacted teeth per patient. Postradiation extraction is fraught with risk of osteoradionecrosis.

NHANES data found 11.88% prevalence of periodontal disease.³² Our data show increased prevalence of this problem with 37.2% CEJ exposed and 31.1% having root exposure on oral examination. Our cohort differs greatly from the asymptomatic patients in whom routine screening detects low rates of pathoses. Moderate and severe periodontal disease can be quantified by degree of bone loss on radiographs, or by probing depth on physical exam.³³ Marcus found that pockets were more prevalent on clinical exam than bone loss visualized on radiographs in moderate-to-severe periodontal disease; however the pervasiveness of periodontal involvement was observed by both methods.³³ Inter-rater reliability is lower using PRET alone for bone loss assessment. We revised PRET to enhance reliability; however, it remains likely that both radiographic and oral evaluations are required. A question addressing tooth mobility was added to OHET.³³

Microorganisms in the dental plaque biofilm are proposed as a predictor of lesion activity, and contributor to periodontitis.^{15,34} Plaque levels and tissue inflammation are captured under gingival and periodontal status assessment of OHET.

Persistent hyposalivation was frequent in our study, 93.9% with dry mucosa and 75.5% with no saliva pool

on floor of mouth.³⁵ Hyposalivation and xerostomia, the perception of dry mouth, are known common and debilitating late side effects for many radiotherapy-treated HNCP.³⁶ Patients' ability to taste, swallow, chew, sleep and wear dentures can be affected. Hyposalivation can result in decreased taste, swallowing dysfunction, dental caries, mucosal injury, burning mouth/tongue symptoms and impair QOL.^{3,4,37-39} Oral health maintenance as outlined by MASCC/ISOO should be applied in these patients.³⁷⁻⁴⁰

A range of radiation-induced trismus from 5% to 47% has been reported.⁴¹ Our study had 10.9% of patients with moderate-to-severe trismus (<30 mm) and 21.8% with mild trismus (30 to 39 mm). Early trismus recognition and referral to physical therapy is paramount because once present, trismus is difficult to treat.⁴²

Validation studies are ongoing. In future studies patients will complete the Vanderbilt Head and Neck Symptom Survey (VHNSS), a validated screening tool for symptom burden in HNCP. Additionally, information regarding prior access to routine dental care, compliance with any prescribed daily topical fluoride use, medical comorbidities and medication usage will be collected. The subjective findings on the VHNSS have been able to identify clinically significant oral health issues pertaining to xerostomia, dental health and trismus.⁴³

Limitations

Although small, this is one of the few studies reporting a comprehensive dental assessment in HNCP. Our population was predominantly white, English-speaking males, only in 1 study patient was edentulous, 14.29% of patients had income <\$20,000 ($n = 42$), while 66% had post-high school education which might introduce bias and limit applicability to other populations.

All oral examinations were performed by one investigator. Interexaminer reproducibility is necessary for further tool validation. This study needs to be performed in different populations. Further use of OHET/PRET is recommended to

continue modification to create a standardized form for future use.

Dentist JR found classifying caries into ICDAS-II categories technically challenging. JR reported difficulty accurately assessing for caries without bitewing radiographs.

While community dentists might find OHET/PRET overly detailed for general use, the goal is to collect sufficient information for research and ensure all relevant oral health issues are assessed. For example, ICDAS-II criteria for visual examination included in OHET raise awareness of progression of demineralization which if acted upon early with fluoride treatment might regress. Awareness of patients' oral health needs prior to initiation of radiotherapy could decrease long-term complications.

Conclusions

Preliminary data indicate that OHET/PRET create a comprehensive screening tool to capture oral health status in HNCP. This study is phase I of a planned project to develop a validated comprehensive oral/dental evaluation in HNCP. Further testing in a larger patient population is ongoing. Clinical trials and routine dental care could employ this grading system and data collection tool to reduce subjectivity, increase sensitivity, monitor OHO in HNCP and evaluate for oral lesions during each stage of the dynamic disease process.

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