Analysis of causal models of diet for patients with head and neck cancer receiving radiation therapy

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ABSTRACT

Purpose: This study seeks to establish causal models of diet which maintain the appetite of head and neck cancer patients receiving radiation therapy.
Sample and methods: We collected data from 208 patients at two radiation doses, 30/50 Gy, using a questionnaire on appetite and analyzed the items using structural equation modeling.
Results: In the causal model for 30 Gy, we established a path using the four intervening variables "ease of consuming foods in smooth forms," "ease of consuming foods with a chewable texture and suitable temperature," "ease of consuming lightly seasoned foods with a flavorful smell," and "overall ease of consuming a given meal" from the temporal relationship between "dietary preferences" and "maintaining appetite while caring for the oral cavity." In the causal model for 50 Gy, we established a path between "ease of consuming foods with a mild temperature and smell," and "maintaining appetite while caring for the oral cavity" using the four intervening variables "ease of consuming foods that are easy to swallow," "ease of consuming foods that dissolve well in the mouth," "ease of consuming foods with a mild taste," and "overall ease of consuming a given meal." The goodness of fit indices for both models were above 0.85 for both the goodness of fit index (GFI) and adjusted GFI (AGFI), and less than 0.08 for root mean square error of approximation (RMSEA), indicating a satisfactory goodness of fit.
Conclusions: Food characteristics help to maintain patient appetite at cumulative radiation doses of 30/50 Gy.

Introduction

The oral cavity and salivary glands must be included in the radiation field during radiation therapy for patients with head and neck cancer. This can lead to adverse effects on the sensory organs, such as dysgeusia (dysfunction of the sense of taste), xerostomia (dry mouth), and oral mucositis (inflammation and ulceration in the mouth) that greatly affect dietary intake (Munshi et al., 2003; Bansal et al., 2004; Shih et al., 2003; Unsal et al., 2006). Medical facilities in Japan face a challenge when providing meals to patients receiving radiation treatment for head and neck cancer. In order to determine diets that are appropriate for patients with adverse effects, a thorough study is needed to clarify the relationship between appetite and the symptoms of dysgeusia,

xerostomia, and oral mucositis that result from increases in cumulative radiation dose.

Results from previous studies investigating the adverse effects that accompany radiation treatment revealed that dysgeusia, xerostomia, and oral mucositis begin to affect patient dietary intake at a cumulative radiation dose of 30 Gy, and this effect increases at 50 Gy (Ogama et al., 2006; Sato and Kamata, 1984; Yamashita et al., 2006; Zheng et al., 2002). In contrast, maintaining patient appetite is critical for sustaining patient dietary intake and retaining a satisfactory nutritional state (Ogama et al., 2010). Patients are likely to battle their illnesses with purpose and desire if they can enjoy their meals and maintain appetite. If healthcare workers can maintain patient appetite even while patients are burdened by adverse events, improvements in mental and physical burdens resulting from radiation therapy could be made by promoting dietary intake. However, dietary content that could mitigate adverse events and maintain appetite has not been sufficiently examined.

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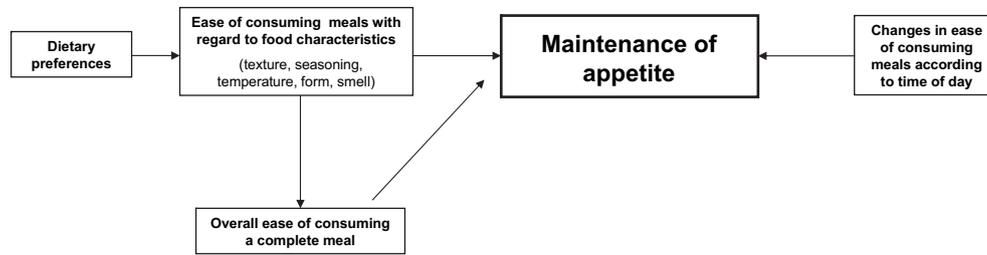E-mail address: oogama@kusw.ac.jp (N. Ogama).

Fig. 1. Conceptual model used as the basis of the study.

Our previous study (Ogama et al., 2006) examined factors that affect the diet of head and neck cancer patients receiving radiation treatment. We demonstrated that food characteristics such as texture, seasoning, temperature, form, and smell, as well as the overall ease of consuming a given meal, affected the maintenance of patient appetite; the ease of consuming meals based on food characteristics was affected by patient dietary preference prior to treatment initiation; and maintenance of appetite was affected by changes in ease of consumption based on the time of day. Based on these findings, we determined that it was necessary to examine the relationship between dietary preference, ease of consumption as related to food characteristics, overall ease in consuming a given meal, and changes in the ease of consumption based on the time of day to determine how these factors influence the maintenance of appetite. In this study, we surveyed head and neck cancer patients with cumulative radiation doses of 30 and 50 Gy in order to clarify causal models of diet which maintain patient appetite.

Structural equation modeling was used as the analytical method in this study for the following reason. In order to consider meals suited to the symptoms of adverse effects, it is necessary to identify the characteristics that most affect patient appetite from among various qualities related to dietary preferences, food characteristics, overall menu, and the time of day when meal is eaten, and then clarify the causal relationship between these characteristics when providing meals. To study the causal relationship between these factors, we explained constructive concepts in order to understand complexly interwoven phenomena in a relatively simple manner. We adopted structural equation modeling because it aims to clarify the causal relationship between those constructive concepts.

Conceptual framework of the study

The conceptual model of this study was created using a baseline study (Ogama et al., 2006) that identified factors affecting the appetite of head and neck cancer patients receiving radiation treatment (Fig. 1). We established that the 3 factors directly affecting "maintenance of appetite" in patients were: "ease of consuming meals based on food characteristics (texture, seasoning, temperature, form, and smell)," "overall ease of consuming a given meal," and "change in ease of consuming meals based on the time of day."

The first factor that directly influences maintenance of patient appetite is "ease of consuming meals based on food characteristics," which comprises the five subordinate concepts of texture, seasoning, temperature, form, and smell. This factor is affected by patient "dietary preferences" prior to treatment, but these preferences represent a culmination of past experiences, habits, and preferences, leading to affective reactions such as "tasty" (Nishinari et al., 2005). In other words, dietary preference is an important indirect factor in terms of maintaining patient appetite while temporally affecting the ease of consuming food based on food characteristics. On the other hand, because this temporal

relationship is not clear in the causal relationship among the five food characteristics, we decided to focus on the five characteristics and leave the temporal relationships unspecified.

The second factor that directly affects the maintenance of appetite is the "overall ease of consuming a given meal," which also serves as an intervening variable to "ease of consuming meals based on food characteristics." The final factor in the model that directly affects the maintenance of appetite is the "change in ease of consumption based on the time of day," which is related to changes over time in symptoms of adverse effects accompanying radiation treatment. Specifically, xerostomia intensifies at times when saliva production is lowest, which is usually in the morning. Mucositis and dysgeusia also intensify synergistically in the morning. These changes result in variability in the ease of meal consumption based on the time of day, which in turn affects the maintenance of appetite (Kuo et al., 1993; Ogama et al., 2010).

Research methodology

Study participants

All study participants received inpatient and outpatient treatment at cancer hospitals in Japan and (1) received treatment by external irradiation with X-rays after being diagnosed with head and neck cancer, (2) received treatment with a planned radiation dose higher than 40 Gy that included the oral cavity in the radiation field, (3) did not receive surgical treatment involving more than

Table 1
Characteristics of Participants.

		N	%	Average ± Standard Deviation
Gender	Male	127	61.1	
	Female	81	38.9	
Age	<49	11	5.3	70.2 ± 10.6
	50–59	25	12.0	
	60–69	65	31.3	
	70–79	71	34.1	
	≥80	36	17.3	
Cancer Location	Tongue	59	28.4	
	Oropharynx	43	20.7	
	Buccal Mucosa	31	14.9	
	Maxillary Gingiva	25	12.0	
	Lower Gingiva	18	8.7	
	Floor of the Mouth	9	4.3	
	Other	23	11.0	
Cancer Classification	Stage I	29	13.9	
	Stage II	32	15.4	
	Stage III	88	42.3	
	Stage IV	59	28.4	
Radiation Dose[a]	≥40 Gy	208	100.0	
	≥50 Gy	197	94.7	

[a] Cumulative dose.

Table 2
Factor analysis results for 30 Gy (*N* = 208).

Item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6
Factor 1: Ease of consuming foods with a chewable texture and suitable temperature						
8) It is easier to consume foods that have a fine texture and are pleasant to the tongue	0.831					
7) It is easier to consume soft foods if some texture is retained	0.809					
2) Rice tastes better when the grainy texture is retained.	0.584					
10) It is easier to eat foods that are not dry	0.539					
24) It is easy to eat hot and cold foods alternately	0.535					
26) It is easy to eat cold foods	0.461					
Factor 2: Ease of consuming lightly seasoned foods with a flavorful smell						
20) It is easier to eat foods without a very spicy taste		0.775				
15) It is easier to eat foods with a good aftertaste		0.769				
13) Very sweet foods are more enjoyable to consume		0.691				
31) Foods with flavorful smells can be eaten comfortably		0.689				
18) Japanese soup stock is easier to consume than Western soup stock		0.482				
19) Clear broth is easier to consume than miso soup		0.425				
Factor 3: Overall ease of consuming a complete meal						
35) Seasonal dishes can be eaten comfortably			0.718			
37) It is easier to consume side dishes cut into small pieces a little at a time			0.649			
39) It is easier to consume dishes that use milk and have a mild taste			0.584			
40) It is easier to consume dishes that are not fried			0.489			
41) It is easier to consume dishes that do not use fermented food			0.377			
Factor 4: Maintaining appetite while taking care of the oral cavity						
45) Chewing and drinking while avoiding oral ulcers maintains appetite				0.713		
43) Selecting meals that are easy to taste maintains appetite				0.686		
42) Selecting mild food maintains appetite				0.532		
44) Adding liquids (soup, drinks) to meals when xerostomia is severe maintains appetite				0.475		
Factor 5: Dietary preferences						
34) Foods normally enjoyed can be eaten comfortably					0.552	
33) Favorite foods prepared according to my tastes can be consumed comfortably					0.462	
47) It is still easy to consume my usual breakfast					0.351	
Factor 6: Ease of consuming foods in smooth forms						
29) It is easy to consume roux-based foods						0.491
27) It is easier to consume solid foods when encased in jelly or dissolvable substances						0.392
30) It is easy to consume noodles						0.380
Total sum of squared loadings after rotation	4.485	3.422	2.948	2.745	3.370	2.549

Factor extraction performed according to maximum likelihood procedure, rotation method performed using a promax rotation.

a partial glossectomy, (4) did not receive simultaneous radiation therapy and chemotherapy, (5) did not have diabetes, endocrine disease, a brain tumor, head injury, or prior or present history of artificial dialysis, and (6) were given an explanation of the study and consented to participate prior to initiation of treatment in addition to fulfilling all of the above criteria.

We excluded patients receiving simultaneous radiation therapy and chemotherapy from the study because previous studies have shown that chemotherapy can cause dysgeusia, xerostomia, and oral mucositis (Berteretche and Dalix, 2004; Alterio et al., 2007; Hutton et al., 2007). The purpose of this study was to test causal models of diet appropriate for patients with symptoms resulting from the adverse effects of radiation therapy alone.

Measurement tools

We administered a questionnaire survey when patients reached cumulative radiation doses of 30 and 50 Gy. The questionnaire comprised 48 items regarding "dietary preferences," "ease of consuming meals based on food characteristics," "overall ease of consuming a given meal," "change in ease of consumption based on the time of day," and "maintenance of appetite." The questionnaire was created based on a preliminary survey and literature review. Each question was scored on a 5-point Likert scale ranging from 1 (I disagree) to 5 (I agree). Five co-researchers, including two registered dietitians, reviewed questions for appropriateness of content, and five patients receiving radiation treatment for

head and neck cancer reviewed the questions for overall appropriateness. The wording and format of the questionnaire were revised based on the reviews.

Transcription of information from medical records

The authors transcribed the following information from medical records: age, sex, name of disease, duration of illness, cumulative radiation dose, and area of irradiation.

Data analysis

At cumulative radiation doses of 30 and 50 Gy, we performed an exploratory factor analysis of all questionnaire items about diet using SPSS 16.0 J for Windows. We then performed structural equation modeling using Amos 16.0 J and reviewed the appropriateness of the models in order to validate the causal model that served as the basis of this study's conceptual framework.

Structural equation modeling hypothesizes latent variables and explains the constructive concepts existing in the background that cannot be directly observed. It is an analytical method that aims to clarify the casual relationships at work in the constructive concept. The causal model is expressed in a path diagram consisting of observed variables (rectangles), latent variables (ovals), and causal relationships (unidirectional arrows). We determined the appropriateness of the model using the goodness of fit index (GFI), adjusted GFI (AGFI), and root mean square error of approximation

(RMSEA). The model was considered appropriate if the GFI and AGFI were greater than 0.85 and if the RMSEA was below 0.08. Statistical significance for this study was set at $p < 0.05$.

Ethical considerations

This study was performed with the permission of the Division of Health Sciences, School of Medicine, Osaka University and its institutional review board. A written explanation was provided to participants to inform them that participation was voluntary, anonymous, and could be discontinued freely; personal information would be handled securely; data would be destroyed following the conclusion of research; and refusal to participate would carry no penalties. Signed consent forms were obtained from participants.

Results

Participant characteristics

Participants were patients receiving radiation therapy at five hospitals that treat cancer in metropolitan areas of Japan who met all inclusion criteria. A brief summary of their characteristics appears in Table 1. The study included 127 males (61.1%) and 81 females (38.9%). Mean age was 70.2 years (SD 10.6). The most common cancer location was the tongue (59, or 28.4%). This was followed by 43 patients with oropharyngeal cancer (20.7%) and 31 patients with buccal mucosa cancer (14.9%). All 208 patients (100%) underwent radiation therapy which included the tongue and oral cavity in the radiation field and received a cumulative radiation dose of at least 40 Gy of radiation. One hundred ninety-seven patients (94.7%) went on to receive a cumulative radiation dose of more than 50 Gy. Accordingly, the analysis was performed on 208 patients at 30 Gy and 197 patients at 50 Gy.

Interpretation and verification of causal models of diet

To create the causal models of diet at cumulative radiation doses of 30 Gy and 50 Gy, we performed exploratory factor analysis (maximum likelihood procedure, promax revolution) of the scores for all questions. We then extracted factors that served as latent variables in the causal models for each dose, postulated the study's conceptual framework, and performed structural equation modeling for the latent variables which resulted from the factor analysis (Tables 2 and 3).

In the causal model for 30 Gy (Fig. 2), two paths were directed from "dietary preferences" to the following two intervening variables: "ease of consuming foods with chewable texture and suitable

Table 3
Factor analysis results for 50 Gy (N = 197).

Item	Factor 1	Factor 2	Factor 3	Factor 4	Factor 5	Factor 6	Factor 7
Factor 1: Ease of consuming foods with a mild taste							
20) It is easier to consume foods without a very spicy taste	0.835						
22) It is easy to consume foods without a very harsh taste	0.742						
21) It is easier to consume foods without the strong taste of soy sauce	0.651						
13) Very sweet foods can be consumed comfortably	0.596						
18) Japanese soup stock is easier to consume than Western soup stock	0.582						
15) It is easy to consume foods with a good aftertaste	0.429						
Factor 2: Overall ease of consuming a complete meal							
37) It is easier to consume side dishes cut into small pieces a little at a time		0.827					
40) It is easier to consume dishes that are not fried		0.768					
39) It is easier to consume dishes that use milk and have a mild taste		0.612					
41) It is easier to consume dishes that do not use fermented food		0.536					
35) Seasonal dishes can be consumed comfortably		0.409					
Factor 3: Ease of consuming foods that dissolve well in the mouth							
4) Foods that melt and are juicy can be consumed comfortably			0.628				
10) It is easier to consume foods that do not feel dry			0.585				
8) It is easier to consume foods that have a fine texture and are pleasant to the tongue			0.540				
6) It is easier to consume soft and fluffy foods			0.382				
Factor 4: Maintaining appetite while taking care of the oral cavity							
45) Chewing and drinking while avoiding oral ulcers maintains appetite				0.762			
44) Adding liquids (soups, drinks) to meals when xerostomia is severe maintains appetite				0.546			
43) Selecting meals that are easy to taste maintains appetite				0.416			
42) Selecting mild food maintains appetite				0.371			
Factor 5: Ease of consuming foods that are easy to swallow							
27) It is easier to consume foods that consist of solids encased in jelly or dissolvable substances					0.756		
28) It is easier to consume smooth liquids					0.458		
30) It is easy to consume noodles					0.365		
Factor 6: Ease of consuming foods with a mild temperature and smell							
32) It is easier to consume foods that do not give off cooking smells						0.537	
26) It is easy to consume cold foods						0.486	
25) It is easy to consume meals that are skin temperature or cooler						0.352	
Factor 7: Changes in ease of consuming meals according to time of day							
48) Appetite increases from morning to noon and night							0.635
46) Breakfast is easiest to consume if it comprises foods that are easy to swallow							0.521
47) It is still easy to consume my usual breakfast							0.445
Total sum of squared loadings after rotation	4.317	3.323	4.181	2.490	2.040	1.522	1.111

Factor extraction performed according to maximum likelihood procedure, rotation method performed using a promax rotation.
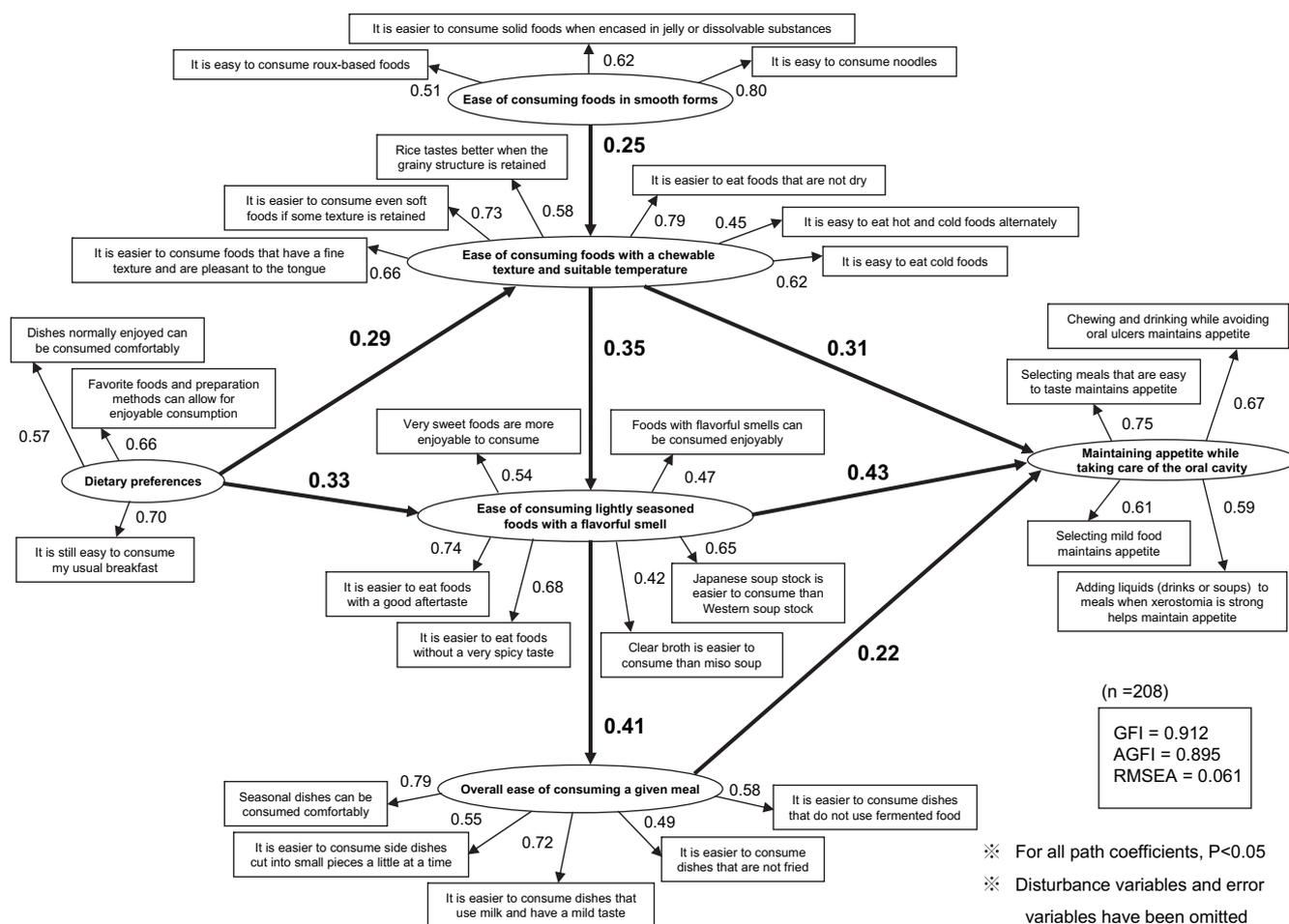
Fig. 2. Causal model of diet at 30 Gy. GFI, goodness of fit index; AGFI, adjusted GFI; RMSEA, root mean square error of approximation.

temperature" and "ease of consuming lightly seasoned foods with a flavorful smell." This indicated that, based on the temporal relationship, an increase in "dietary preferences" elevated "ease of consuming foods with a chewable texture and suitable temperature" and "ease of consuming lightly seasoned foods with a flavorful smell". Among the subordinate concepts on food characteristics, we confirmed that "ease of consuming foods in smooth forms" increased "overall ease of consuming a given meal" through "ease of consuming foods with a chewable texture and suitable temperature" and "ease of consuming lightly seasoned foods with a flavorful smell". Additionally, "maintaining appetite while caring for the oral cavity" at 30 Gy was influenced by the three latent variables, of which "ease of consuming lightly seasoned foods with a flavorful smell" showed the strongest influence.

In the causal model for 50 Gy, we could not extract latent variables on dietary preferences that presume a temporal relationship (Fig. 3), and no clear temporal relationship was observed among latent variables on food characteristics (texture, seasoning, temperature, form, and smell). This allowed for a relatively easy establishment of paths. The causal model for 50 Gy indicated that an increase in "ease of consuming foods with a mild temperature and smell" elevated both "ease of consuming foods that dissolve well in the mouth" and "ease of consuming foods with a mild taste". We also confirmed that "ease of consuming foods that are easy to swallow" increased "overall ease of consuming a given meal" through both "ease of consuming foods that dissolve well in the mouth" and "ease of consuming foods with a mild taste". At 50 Gy, "maintaining appetite while caring for the oral cavity" was directly

influenced by the four latent variables, of which "ease of consuming foods that dissolve well in the mouth" and "ease of consuming foods with a mild taste" had the strongest influence. Furthermore, "change in ease of consumption based on the time of day" influenced "maintaining appetite while caring for the oral cavity", a result different from that of the causal model for 30 Gy.

Table 4 displays the characteristics of dietary preference, food characteristics, given meals, and change in ease of consumption based on the time of day, all of which affect appetite. These characteristics were based on latent and observed variables comprising the causal models for 30 Gy and 50 Gy.

The GFI and AGFI were greater than 0.85 and RMSEA was less than 0.08 for the models at both doses. Path coefficients for causal relationships between factors ranged from 0.22 to 0.43 in the 30 Gy model, and from 0.21 to 0.48 in the 50 Gy model. In each model, path coefficients were statistically significant ($p < 0.05$). From these results, we concluded that both causal models of diet were appropriate.

Discussion

The two causal models (30/50 Gy) generated from the questionnaire survey are likely to become fundamental sources for obtaining suggestions on nursing care which allow for patients to enjoy their meals even while being burdened with adverse events.

The causal model for 30 Gy demonstrated that "dietary preferences" of patients increased both "ease of consuming foods with a chewable texture and suitable temperature" and "ease of
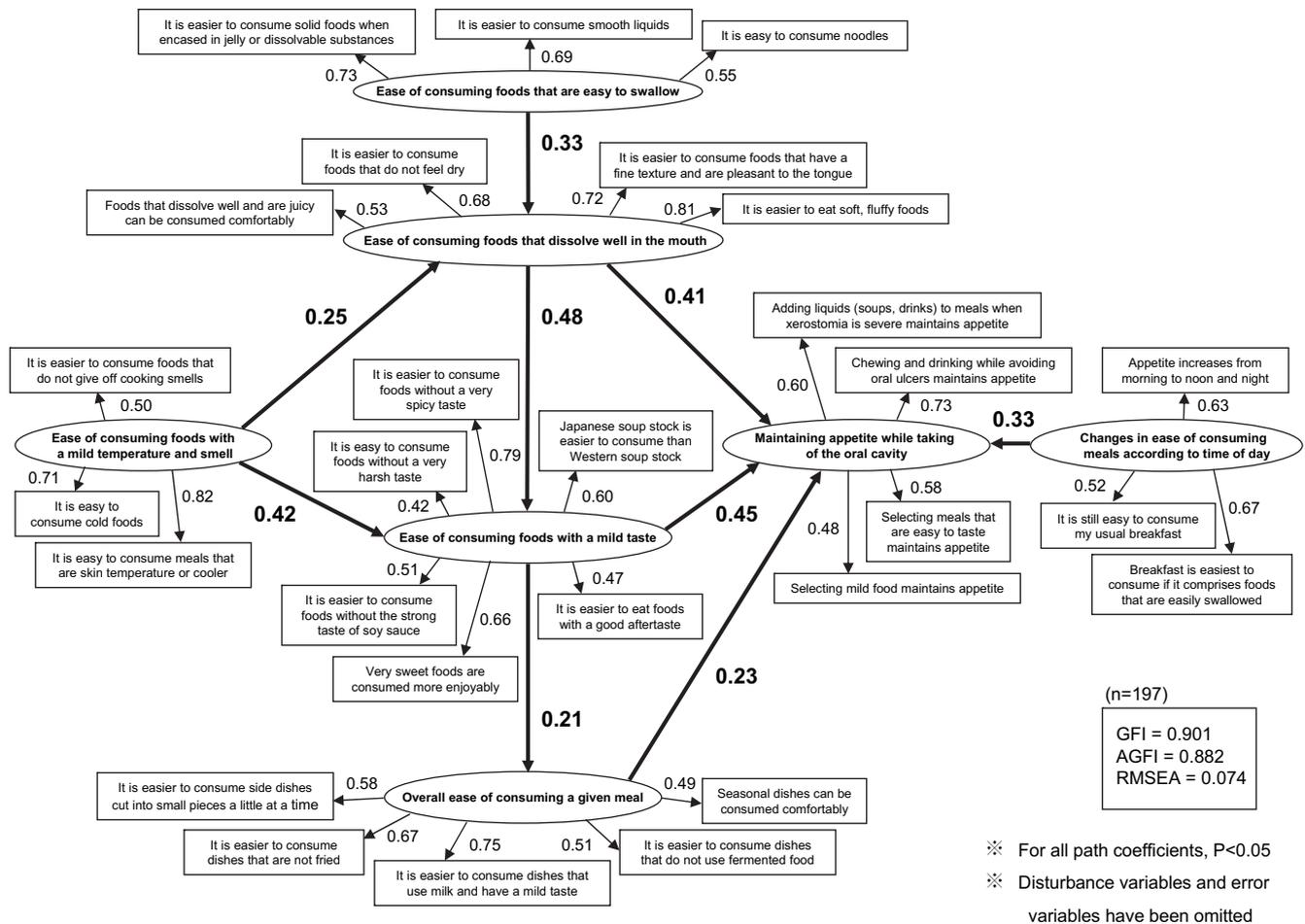
Fig. 3. Causal model of diet at 50 Gy. GFI, goodness of fit index; AGFI, adjusted GFI; RMSEA, root mean square error of approximation.

consuming lightly seasoned foods with a flavorful smell." One's dietary preferences increase the enjoyment of meals while being affected by food characteristics (Nishinari et al., 2005). Furthermore, meal enjoyment increases due to the synergistic effects of texture and temperature (Kadohisa et al., 2004), and seasoning and smell (Yamaguchi, 1998). The results of this study suggest that the preferences of head and neck cancer patients receiving radiation treatment are in a causal relationship with the specific combinations of texture and temperature, and seasoning and smell. Based on this, it appears that providing meals that reflect patient preferences prior to treatment increases the ease of consumption due to texture and temperature, and seasoning and smell, and can help maintain the appetite of patients living with these adverse effects.

In the causal model for 30 Gy, we observed the following causal relationships in the path in the following order: "ease of consuming foods in smooth forms," "ease of consuming foods with a chewable texture and suitable temperature," "ease of consuming lightly seasoned foods with a flavorful smell," and "overall ease of consuming a given meal." First, "ease of consuming foods in smooth forms" increases "ease of consuming foods with a chewable texture and suitable temperature." In this causal relationship, smooth food forms affect chewable texture and the suitable temperature when food is placed in the mouth without intensifying the pain resulting from xerostomia and oral mucositis. For this reason, the relationship likely indirectly increases the overall ease of consuming a meal. Furthermore, causal relationships among food form, texture, and temperature affect the "ease of consuming lightly

seasoned foods with a flavorful smell." Rolls (2004) found that oral cavity sensations such as form, texture, and temperature of food influence gustatory and olfactory perceptions to enhance the taste of a meal. That is, the "overall ease of consuming a meal" likely increases synergistically as smooth food form, chewable texture, and suitable temperature affect flavorful smells despite light seasoning, thereby enhancing gustatory sensitivity and olfaction without intensifying pain resulting from xerostomia or oral mucositis.

The causal model for 50 Gy showed that "ease of consuming foods with a mild temperature and smell" increased both "ease of consuming foods that dissolve well in the mouth" and "ease of consuming foods with a mild taste." Among other adverse events, xerostomia and pain caused by oral mucositis are main factors that decrease food intake of patients at 50 Gy (Sharp et al., 2008). This causal model for 50 Gy indicated that synergetic effects of consuming foods with a mild temperature and smell, for example avoiding meals at body temperature or cooler or the smell of heated foods, would increase "ease of consuming foods that dissolve well in the mouth and with a mild taste." We also assumed that such effects maintain the appetite of patients with xerostomia or pain caused by oral mucositis.

In the model for 50 Gy, the direction of the path indicated that "ease of consuming foods that are easy to swallow" increased "overall ease of consuming a given meal" through "ease of consuming foods that dissolve well in the mouth" and "ease of consuming foods with a mild taste." The causal relationship

Table 4
Characteristics that affect appetite in head and neck cancer patients during 30/50 Gy treatment: dietary preference, food characteristics, given meals, and changes in ease of consumption based on the time of day.

	30 Gy of cumulative radiation	50 Gy of cumulative radiation	
Dietary preference	■ Ingredients and preparation methods a patient likes ■ Meals a patient frequently consumed prior to treatment	Temperatures and smells providing minimal stimulation	[Minimally stimulating temperatures] ■ Chilled foods such as appetizers ■ Temperatures that approximate human skin [Minimally stimulating smells] ■ Meals that avoid the smell of heated food
Smooth food forms	■ Food forms in which solid foods are thickened with cornstarch, butter, vegetable oil, or roux ■ Food forms in which solid foods are wrapped in gelatin ■ Food forms with smooth textures, such as noodles		
Easily chewed textures and appropriate temperatures	[Foods that are easily chewed] ■ Finely textured ■ Foods that are soft but not mushy ■ Cooked rice with firmer grain-texture ■ Foods that are not dry [Appropriate temperatures] ■ Efforts to serve warm and cold foods at the same time, or to alternate them when feeding the patient ■ Chilled foods such as appetizers	Easily swallowed food forms Foods that dissolve well in the mouth	■ Food forms in which solid foods are thickened with cornstarch, butter, or vegetable oil ■ Food forms in which solid foods are wrapped in gelatin ■ Light and refreshing soups ■ Food forms with smooth textures, such as noodles ■ Foods that have a tender juiciness ■ Finely textured ■ Soft and fluffy texture ■ Texture that has no dryness
Light seasoning and flavorful smells	[Light seasoning] ■ Seasoning that brings out the sweetness in foods ■ Japanese stock rather than Western broths ■ Clear Japanese soups rather than miso-based soups ■ Seasonings that provide a pleasant aftertaste in meals centered around Japanese dishes ■ Seasonings that are not overly spicy [Flavorful smells] ■ Food such as Japanese cooking that is flavorful and has a solid smell	Seasoning that provides minimal stimulation	■ Seasonings that avoid heavy soy sauce flavors ■ Seasonings that avoid scum ■ Seasonings that avoid spicy flavors ■ Seasonings that bring out the sweetness in foods ■ Japanese stocks rather than Western broths ■ Seasonings that provide a pleasant aftertaste in meals centered around Japanese dishes
Given meals overall	■ Meals in which multiple side dishes are presented in small servings ■ Meals that convey the season ■ Meals that include mild foods containing milk ■ Meals that do not include fried foods ■ Meals that do not include fermented foods	Given meals overall	Same as the characteristics for overall meals for 30 Gy
		Change in ease of consuming meals depending on time of day	■ For breakfast, it is easier to consume food to which the patient is already accustomed ■ For breakfast, it is easier to consume meals that are easily swallowed ■ Appetite increases in the following order: morning, noon, evening

between these four latent variables also seems closely related to the pain that arises from oral mucositis. In other words, thick, smooth liquids and noodles that can be easily swallowed increased the ease of consuming foods that dissolve well in the mouth and on the tongue. Moreover, it appears that an increase in the ease of consuming mildly seasoned foods with a texture that dissolves well in the mouth leads to an increase in the "overall ease of consuming a given meal" without increasing pain.

Among the four latent variables that directly affect "maintaining appetite while caring for the oral cavity," the corollary of the 50 Gy model, "change in ease of consumption based on the time of day" was additionally shown to affect "maintaining appetite while caring for the oral cavity," unlike in the 30 Gy model. This may be because xerostomia symptoms are greatly influenced by within-day fluctuations. Kuo et al. (1993) demonstrated that saliva production in patients receiving radiation treatment for head and neck cancer decreases the most during the period between night and morning. Also, symptoms of oral mucositis and dysgeusia reportedly worsen following the intensification of xerostomia (Ogama et al., 2010). In other words, because dysgeusia and oral mucositis worsen synergistically as xerostomia intensifies in the morning, meal intake may be the most difficult during morning hours. Accordingly, in order to "maintain patient appetite while taking care of the oral cavity," medical personnel should pay attention to the time period when it is easiest for patients to eat, and provide effective support by pursuing innovations in ingredients and preparation methods appropriate for patients with dysgeusia, oral mucositis, and xerostomia.

Indications for care-giving success and topics for further study

The causal models for diet at 30 Gy and 50 Gy provide several hints about caring for the dietary needs of patients receiving radiation treatment for head and neck cancer. In addition to considering dietary preferences at 30 Gy, meals should be provided that take into consideration the causal relationships among the food characteristics of smooth form, chewable texture, and suitable temperature, and a light seasoning and flavorful smell, in order to increase the patient's overall ease of consuming a given meal. Patient appetite can be maintained at this dosage level by providing meals comprising lightly seasoned foods with a flavorful smell. Providing meals to patients who have received more than 50 Gy that take into consideration the causal relationships among forms that are easily swallowed, textures that dissolve well in the mouth, and lightly seasoned foods, while also paying attention to food characteristics such as mild temperature and smell, may increase the overall ease of consuming a given meal. Moreover, foods that dissolve well in the mouth and are lightly seasoned are particularly effective in maintaining patient appetite at this dosage level. It is also important for medical professionals to be creative with regard to contents of meals in addition to paying attention to times of the day when patients can consume meals easily.

Based on the indications for care-giving success mentioned above, it will be necessary to consider devising menus and preparation methods that are suited to the symptoms of adverse effects that change with each cumulative radiation dose. Additionally, with regard to providing meals for patients who undergo radiation treatment, it will be important to investigate not only the relationships addressed in this study among dietary preference, food characteristics, given meals, the time of day, and appetite for food intake, but also the location and size of the cancer, the part of the body being irradiated, the patient's nutritional condition, the environment in which the patient consumes meals, and the amount of food consumed.

Conflict of interest statement

All authors have read and approved the manuscript. No conflicts of interest exist.

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