Evaluation of Dental Terminology System Using GRAIL : A Pilot Study

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CONTENTS

Ⅰ. INTRODUCTION

In recent years, there has been an enlarged use of more detailed medical terminologies and an increasing requirement for re-usable medical terminologies in computer-based medical information systems. However, the traditional classifications, nomenclatures, and coding systems cannot provide the required level of detailed and re-usable medical terminologies, because they cannot define how medical concepts are to be referenced and they have been developed for a specific purpose.[1)] These increasing demands on terminologies has resulted in a qualitative change in the requirements placed on the traditional coding and classification schemes.[2,3,4)]

As the alternative method, a formalism, such as GRAIL (the GALEN Representation and Integration Language), has been suggested.[1,3)] GRAIL was developed in GALEN (Generalized Architecture for Languages, Encyclopedias, and Nomenclatures in Medicine) project.[5)] GALEN is a project developing terminology servers and data entry systems to represent medical concepts in a semantic network.[3,4,6)] The network allows for the combination and specialization of concepts to the required level of detail. GALEN aims to support the flexibility required to cope with the diversity amongst medical applications, while ensuring the coherence necessary for integration and re-use of terminologies.[5)] GALEN aims to build a compositional generative model for medical terminology.[4,7)] This model is called the GALEN Common Reference Model, or shortly, GALEN CORE model, which is the central feature of GALEN.[1,8)] It is being developed to represent all and only sensible medical concepts and to be accessible and manipulated by computers.[8)]

The development of standardized dental terminology has been an important part of dental field. There is increasing evidence to show that traditional taxonomic vocabularies are unsuitable for capturing detailed dental clinical data. Considering these facts, representation of dental knowledge with GRAIL is valuable for development of its various clinical

applications. Up to now, there have been few researches in concept modeling concerned with dental terminology, compared with previous researches in GRAIL modeling of medical and nursing terminology. These researches must be performed considering special characteristics of dentistry, not merely applying methodologies used in researches in medical and nursing terminology. In other words, dental concept modeling by using GRAIL must be based on the knowledge of head and neck anatomy, oral physiology, oral pathology, occlusion and clinical dentistry.

We performed the concept modeling of about 200 anatomical structures in the region of head and neck and about 50 oral and maxillofacial diseases, using GRAIL. Then, we evaluated the formulated model to demonstrate whether GRAIL and GALEN CORE model can be suitably applied in dentistry, especially in computer-based dental patient records. This paper describes how GRAIL is being used to develop a representation of dental terminology that will be sufficiently expressive for documenting detailed clinical data while retaining the benefits of traditional taxonomic vocabularies.

Ⅱ. MATERIALS AND METHODS

1. Materials

1. GALEN, GRAIL and GALEN CORE model

GALEN (Generalized Architecture for Languages, Encyclopedias, and Nomenclatures in Medicine) was an EC (The European Commission) funded project,[3,6] conducted from 1992 to 1995 and its succeeding projects have been developed up to now. Many research centers were involved in this project, including University of Manchester, Hewlett-Packard Ltd., and other nine research centers.[9] The purpose of GALEN project is to develop a language for representing clinical information in a way that makes it accessible and usable for both people and computer systems. The language developed in GALEN is known as GRAIL (the GALEN Representation and Integration Language).[3,10] The model formulated by GRAIL, is called the GALEN Common Reference Model or GALEN CORE model,[7] which is the central feature of the GALEN.[8] GALEN CORE model consists of a network of nodes called entities, and statements labeled by special kinds of entities called attributes. In other words, it consists of a hierarchy subsumption of elementary entities and a set of sanctioning statements connecting these entities.[1,11] Six thousand primitive or composite categories were presented in 1996 and the number of categories was expanded to 8000 at the beginning of 1997.[7]

For modeling dental concepts in the present study, essential basic structures of the established GALEN CORE model were adopted, while some parts related to dental concepts were corrected or added.

2. KnoME

A GRAIL model were built, browsed and evaluated using KnoME (Knowledge Modeling Environment). KnoME is the modeling environment that has been developed in the GALEN project to support the production of GRAIL models.[12] It is one of software tools that allow modelers to create, view, explore and maintain a GRAIL model. In other words, KnoME is a software tool for building, browsing and evaluating a GRAIL model. Actually, it can make a GRAIL model accessible and manipulable by computers.

KnoME is an overall term for three separate tools - KnoME-lite-browser, KnoME-lite-extender, and KnoME-lite-pro.

KnoME-lite-browser is intended to support the browsing and exploration of the model, without adding any additional knowledge to the system. KnoME-lite-extender is designed to support well-controlled additions to the model. KnoME-lite-pro is designed to support the overall building and maintenance of the model.

In the present study, the dental concept model were made mainly using KnoME-lite-pro with both functions of editing and browsing.

2. Methods

1. Modeling process of dental concepts

Modeling dental concepts includes two important steps.[13] The first step is to standardize dental terminologies by defining the elements of dental knowledge. It means the precise definition of each term used in the dentistry and the semantic relationships between the terms. The second step is the structuring stage, organizing the elements of dental knowledge in an appropriate model.[14]

The followings are the whole steps of modeling of dental knowledge.

(1) Selection of suitable dental terms for modeling

To select suitable dental concepts for modeling GRAIL models, dental records of 150 patients who have visited Seoul National University Dental Hospital, were reviewed. The selected patients' records contained the histories of comprehensive dental management including operative, periodontal, prosthetic treatments, etc. The contents of the dental records were classified into chief complaint, present illness (onset, course, now), past dental history and past medical history. Main dental terms were extracted from these classified contents, in the view of frequency in use. Of the extracted terms, some terms related to anatomy and diseases in oral and maxillofacial region, were selected. Finally, suitable dental concepts for modeling were selected. A lot of dental terms were also reviewed from popular textbooks about head and neck anatomy and oral pathology.[15-25] Especially for modeling oral diseases, ICD-DA (The International Classification of Diseases -Dental Application (3rd edition, 1995)) was reviewed and suitable dental concepts were selected.[19]

(2) Analysis of dental terminologies

1) Extraction of dental concepts from the selected dental terms

Selected concepts of dental anatomical structures and diseases were further divided. Each of them had various sub-terms in itself.[15-25] From these elements, candidates for suitable dental concepts for modeling were extracted.

2) Establishment of the relationships among dental concepts

① Analysis of dental concept hierarchies

Among extracted dental concepts, some were closely related to each other, but others did not. Dental concepts with close relationship were grouped, and the relationships of these groups were analyzed. Then, their hierarchies were made. The meaning of this procedure was to find groups of terms that had 'is-a kind of' relationships.[8]

② Definition of the relationships among dental concepts

On the basis of their analyzed relationships, relationships among dental concepts were described, with reference to the attributes used in GRAIL model.[8]

(3) GRAIL expression of dental concepts

The next step was to translate the constructed hierarchies and definitions into GRAIL. In other words, selected dental concepts and the whole relationships described through natural languages were changed into GRAIL expression.

(4) Compiling and debugging translated dental concepts using KnowME

KnowME contains the section called 'workspace', where the modeler can input GRAIL expressions.[12] On this section, dental concepts expressed using GRAIL, were compiled with KnoME, to manipulate them with computers. And, compiled dental concepts were debugged with KnowME.

2. Evaluation of the constructed dental concept model

After modeling, it was demonstrated whether the constructed model was suitable for application in dentistry. The followings are the total steps of evaluation of constructed dental concept model. First, lots of queries related to dental concepts were made to evaluate correctness of the constructed model. The contents of the queries included

incorrect statements as well as correct ones. Second, these queries were performed with KnoME and browsed.[12] Then on the screen, answers to the queries were displayed in the form of hierarchies.[12] Third, The results of queries were checked to detect errors in them. If there are any structural faults in a GRAIL model, KnoME shows error message on the screen and if the model is sound in structure, KnoME presents the correct hierarchies as the answer to the query.

Ⅲ. RESULTS

1. Selected terms which were primarily necessary to model

Table 1 represents the terms that were selected from 150 dental patient records and were primarily necessary to model. They were divided into two categories - anatomical structures and oral and maxillofacial diseases. Tooth was used most frequently in the category of anatomical structures and dental caries was used most frequently in the category of oral and maxillofacial diseases.

2. The modeling of anatomical structures in oral and maxillofacial region

(1) The modeling of tooth

1) The hierarchy of tooth

The hierarchy of tooth was constructed under three criteria (anatomical shape of tooth, anatomical position of tooth in oral cavity and physiological function of tooth)(Fig. 1).[25]

2) The parts which constitute the tooth

Components of tooth were separated under three aspects (substance, solid structure and surface), according to the established GALEN CORE model(Fig. 2). Each part, which constitutes tooth, can be further divided, according to anatomy.[25]

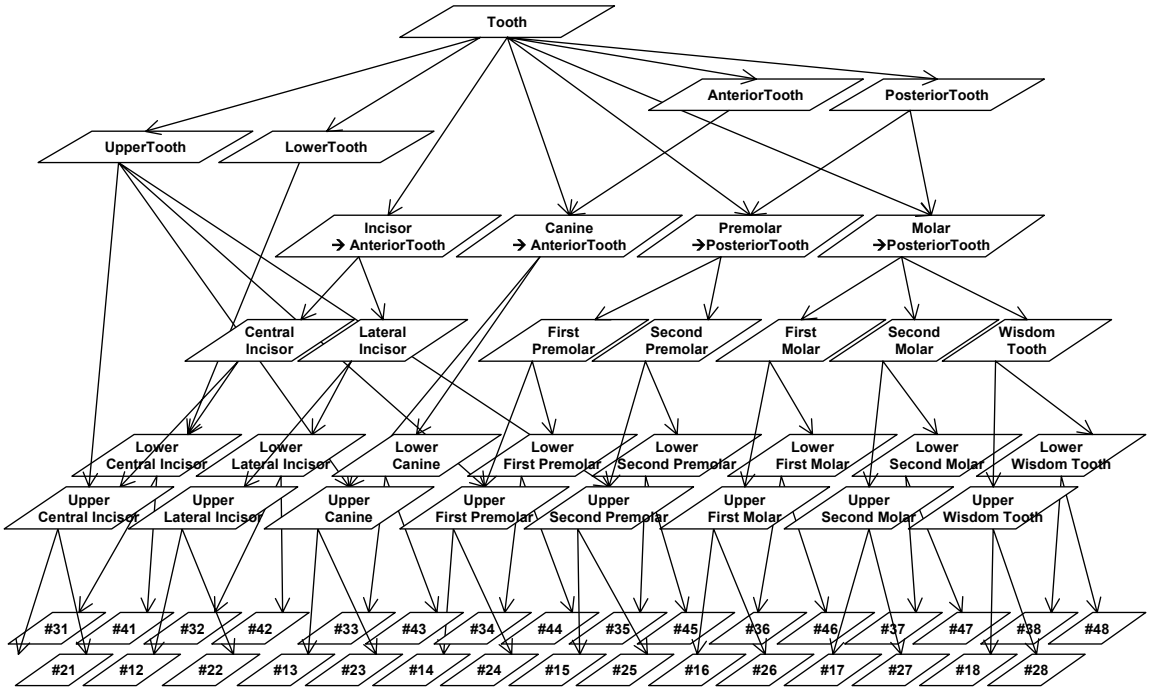

Fig. 1. The hierarchy of tooth

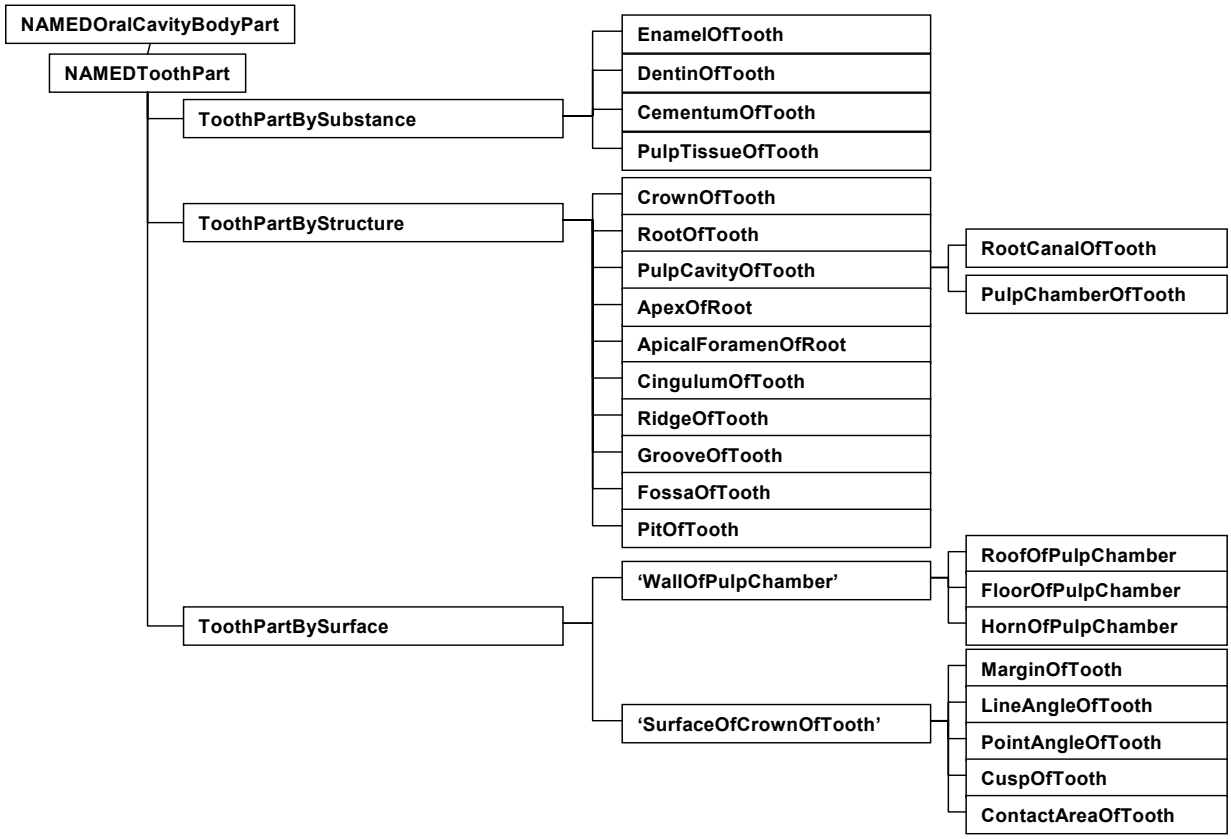

Fig. 2. The parts which constitute tooth

3) The relationship between the tooth and it's parts

Overall relationships among each tooth having its specific anatomic structures or surfaces, are shown in Fig. 3a, Fig. 3b.[25]

After collecting these results related to modeling of tooth, GRAIL expression of the constructed model of tooth was made.

(2) The modeling of periodontium

1) The modeling of alveolar bone

Alveolar bone had been already modeled in the established GALEN CORE model. Alveolar bone was considered as a part of jaw (maxilla or mandible) in the established GALEN CORE model.

2) The modeling of periodontal ligament

GRAIL expression of the constructed model of periodontal ligament was made additionally. Positional relationship with adjacent structures is a critical criteria to describe periodontal ligament using GRAIL(Fig. 4).[21,22]

3) The modeling of gingiva

Gingiva was considered as a kind of oral mucous membrane in the established GALEN CORE model. So, gingiva was described as a part of oral mucous membrane in the dental concept model, too.

(3) The modeling of oral mucous membrane, tongue, and lip

The hierarchies of oral mucous membrane, tongue and lip were established(Fig. 5, 6).[23,24] Then, the GRAIL model of oral mucous membrane, tongue, and lip was constructed.

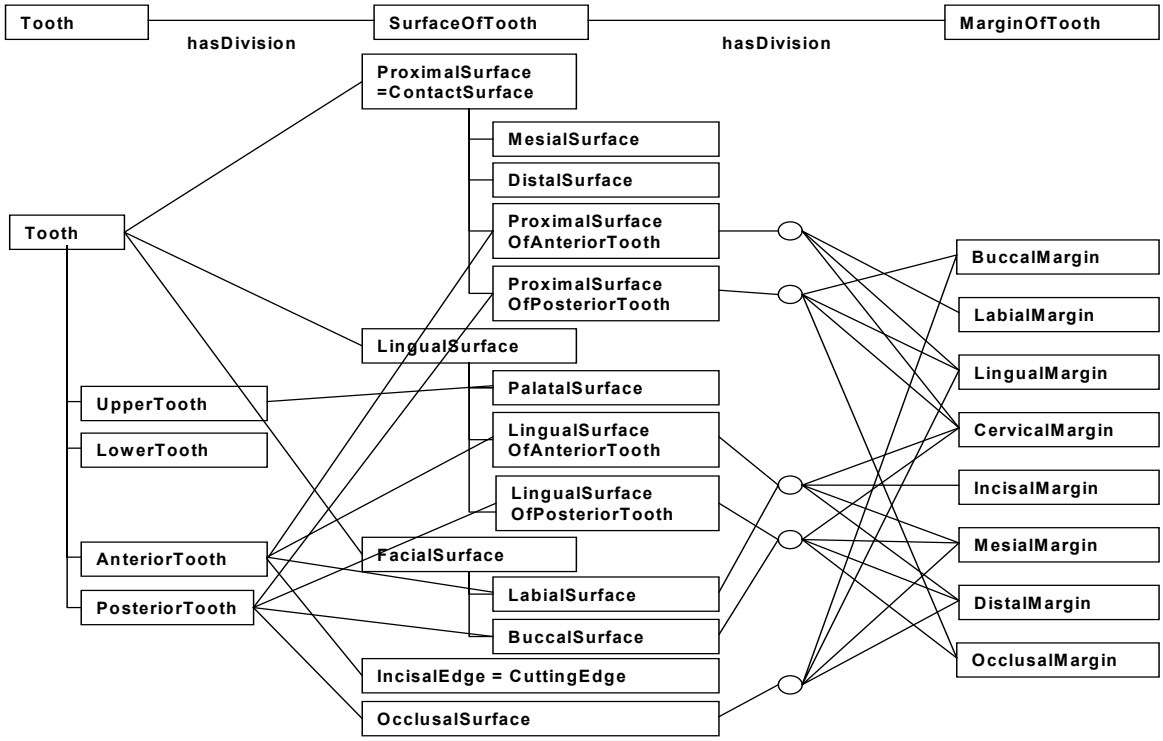

Fig. 3a. The relationship between tooth and it's parts

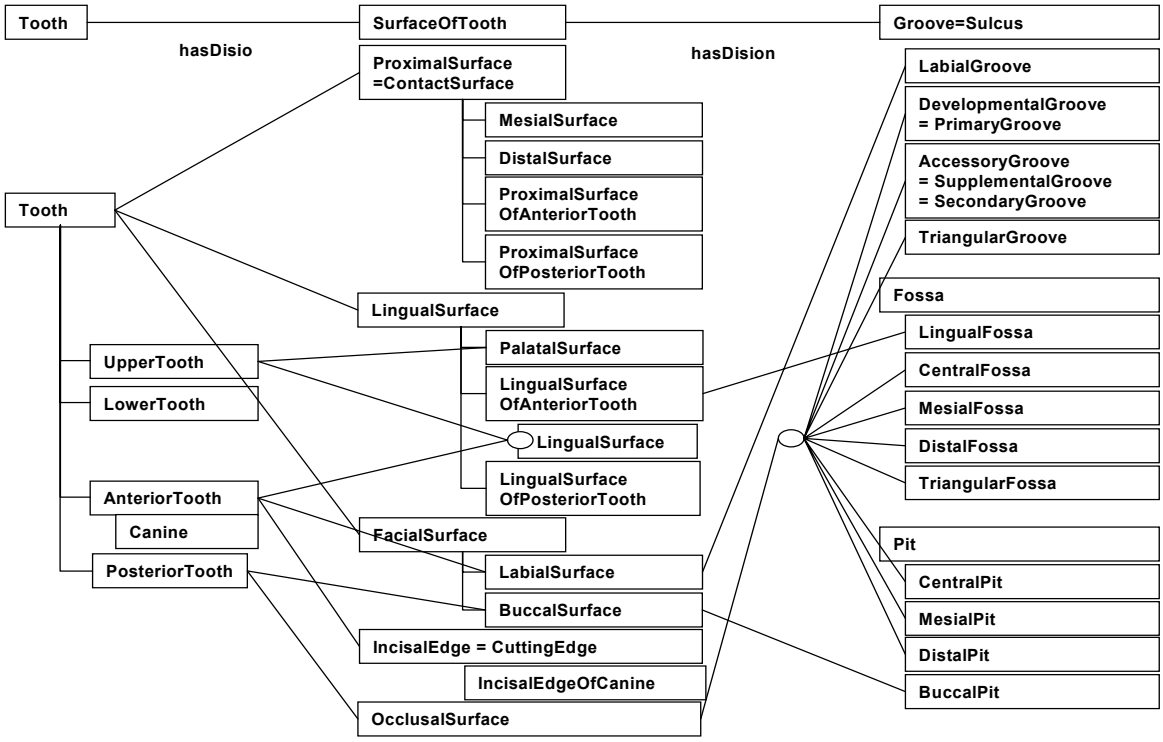

Fig. 3b. The relationship between tooth and it's parts

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(Ligament whichG isStructuralComponentOf mouth)
    name PeriodontalLigament.
PeriodontalLigament sensiblyAndNecessarily
isFrom AlveolarPartOfBone.
PeriodontalLigament sensiblyAndNecessarily
isTo CementumOfTooth
```

Fig. 4. The GRAIL expression of periodontal ligament

Table 1. Main key words for GRAIL modeling

Categories	Key words
Anatomical structure	Tooth
	Gingiva
	Tempromandibular joint
	Lip
	Jaw
	Tongue
Oral and maxillo facial disease	Dental caries
	periodontitis
	Gingivitis
	Temporomandibular disorders
	Impaction of wisdom tooth
	Cervical abrasion

3. The modeling of oral diseases

(1) The modeling of dental caries

Fig. 7 indicates the hierarchy of dental caries.[16] Selected concepts of disease were based on ICD-DA and some concepts, such as smooth surface caries, were added to satisfy the clinical requirements. According to the hierarchy, the concept modeling of dental caries was performed using GRAIL.

(2) The modeling of pulpal and periapical diseases

There is the hierarchy of pulp and periapical diseases in Fig. 8.[16,18] Concepts of pulpal and periapical diseases for modeling were selected based on ICD-DA and suitable GRAIL expressions for the concepts were made.

(3) The modeling of diseases of periodontium

The hierarchy of diseases of periodontium was constructed(Fig. 9). Selected concepts were separated into gingival disease and periodontal disease.[21,22] According to the constructed hierarchy, the GRAIL expressions of diseases of periodontium were made.

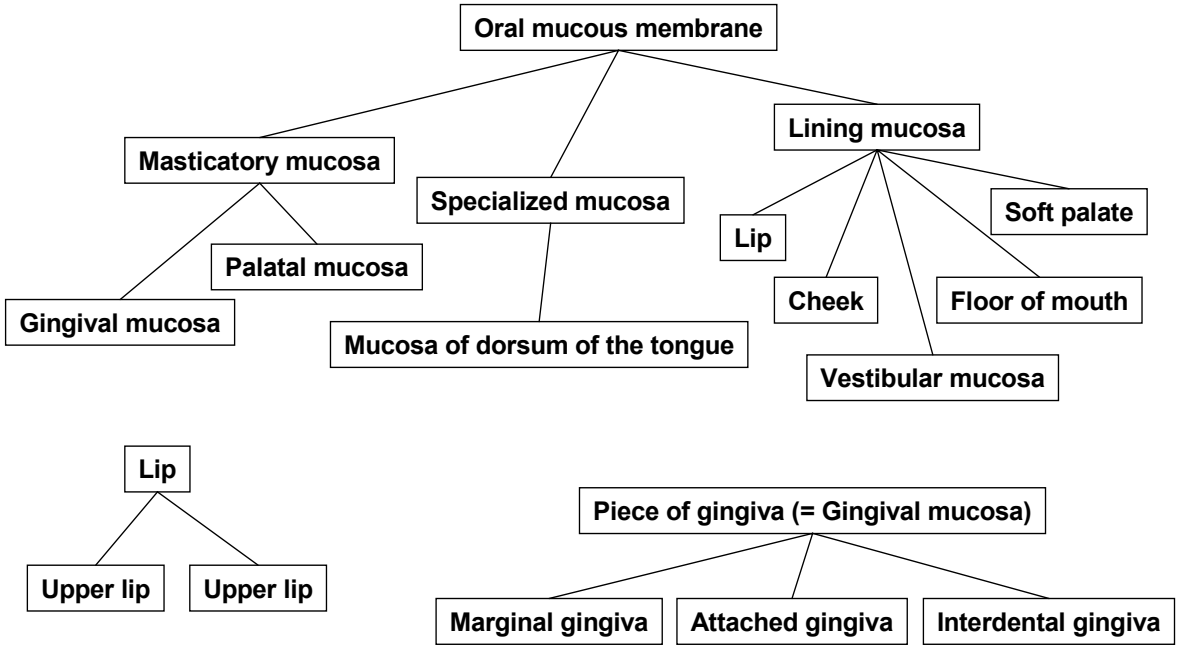

Fig. 5. The hierarchies of oral mucous membrane, lip and gingiva

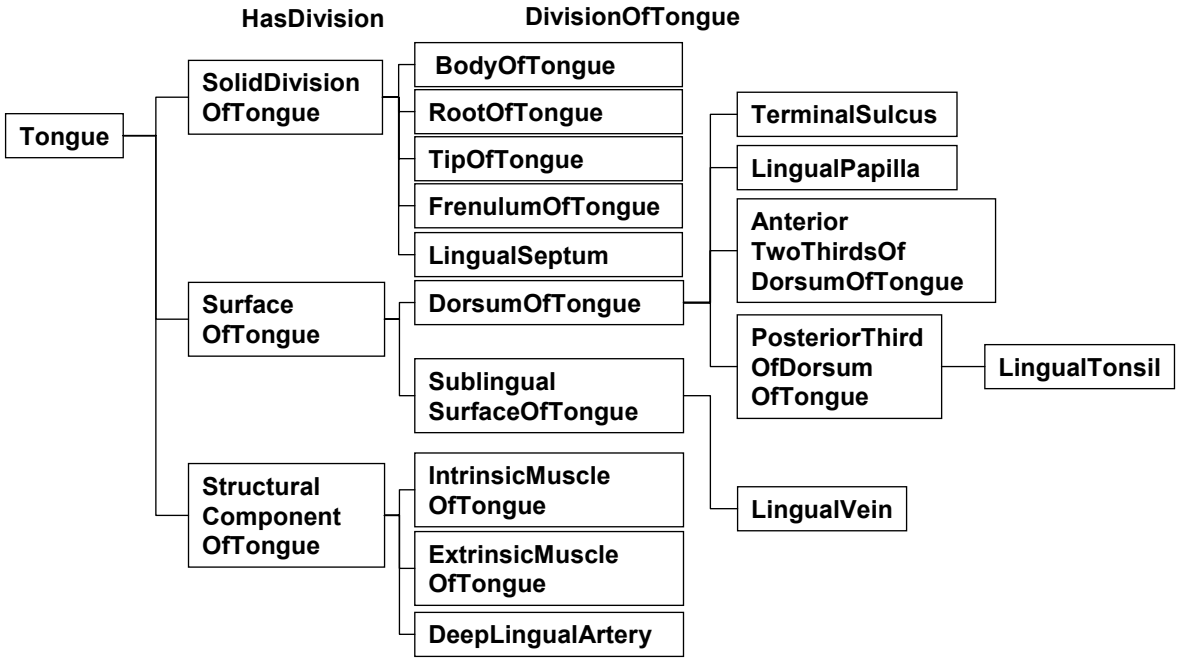

Fig. 6. The relationship between ongueand its parts

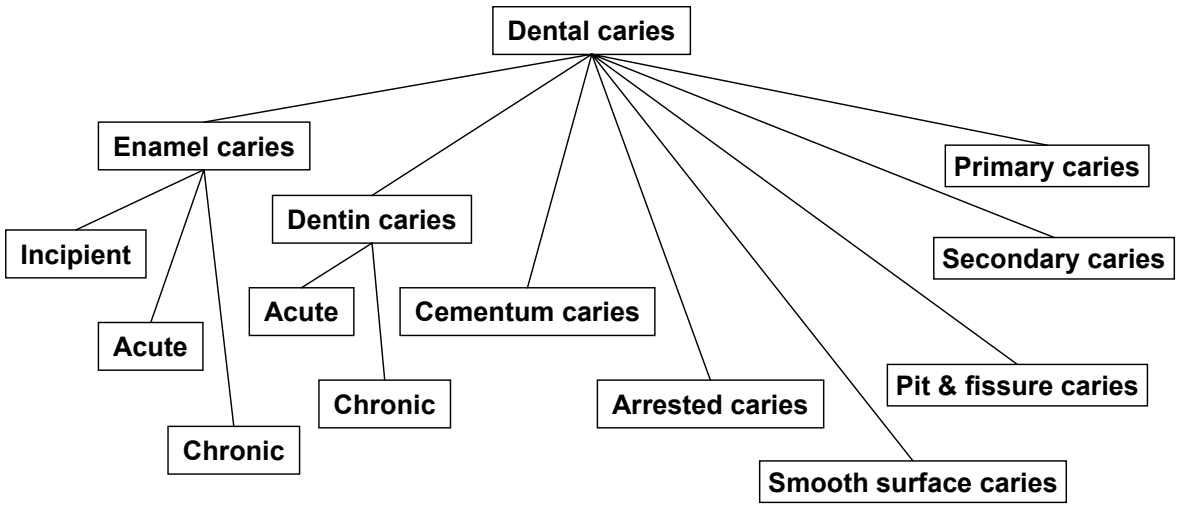

Fig. 7. The hierarchy of dental caries

(4) The modeling of diseases of oral mucous membrane, lip and tongue

Fig. 10 and 11 represent the hierarchies of disease of oral mucous membrane, lip and tongue.[15-17] Concepts for modeling were selected with reference to ICD-DA, and they were expressed using GRAIL.

4. Evaluation of the constructed model

There were the various queries related to dental concepts to evaluate correctness of the formulated model. All answers to the queries were displayed in the form of hierarchies. All dental concepts used as elementary entities in the model were subsequently

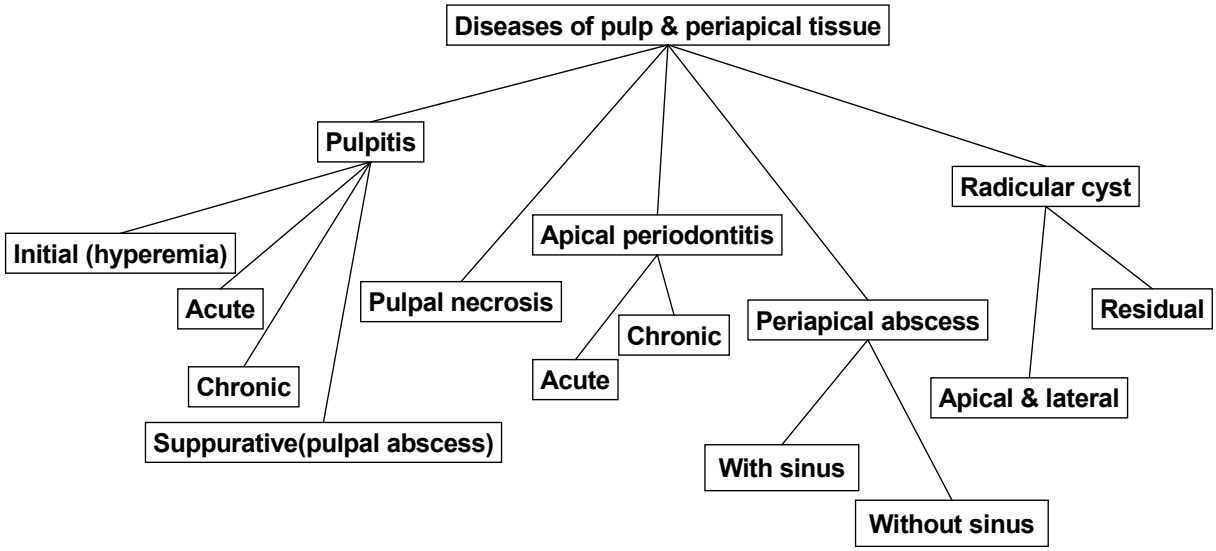

Fig. 8. The hierarchy of diseases of pulp and periapical tissue

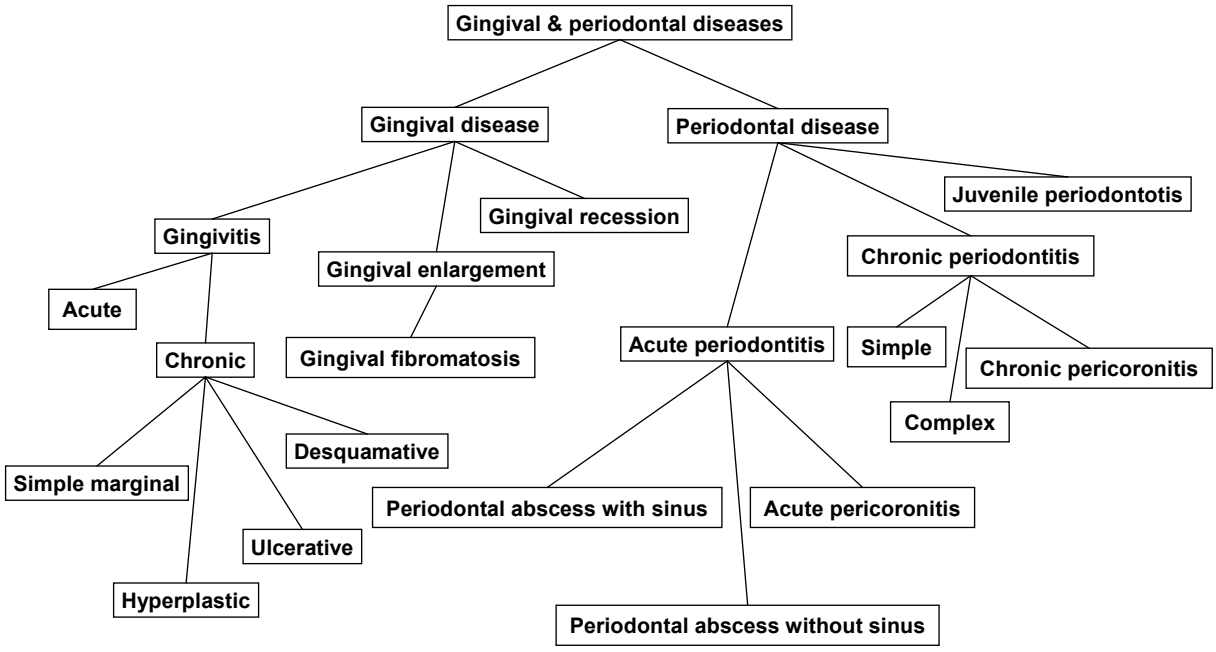

Fig. 9. The hierarchy of gingival and periodontal diseases

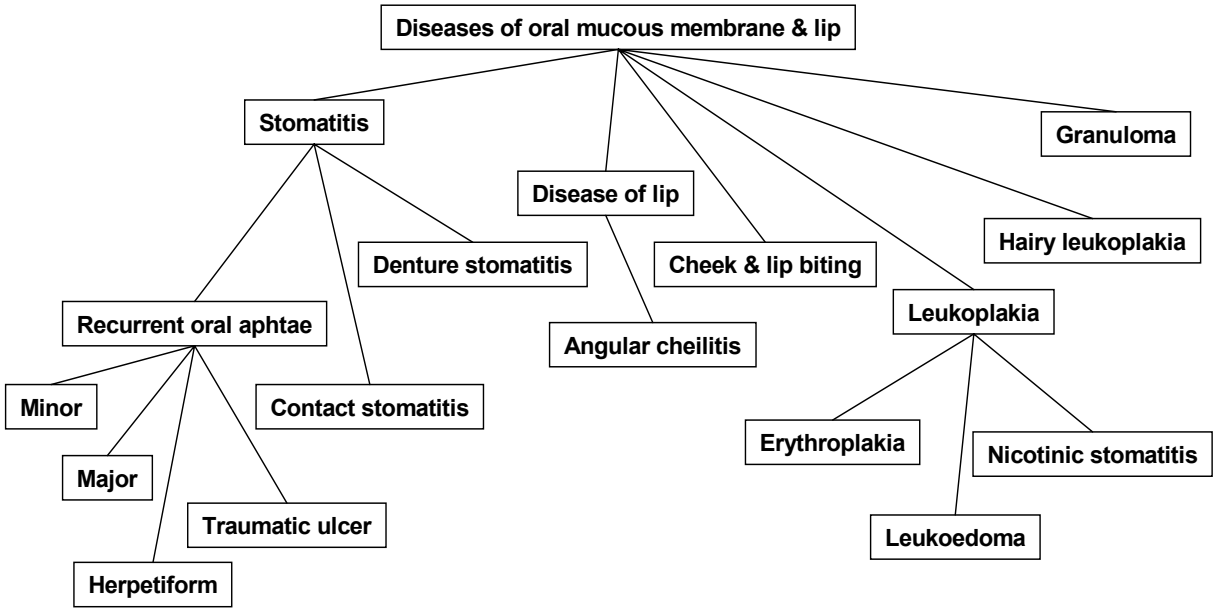

Fig. 10. The hierarchy of diseases of oral mucous membrane & lip

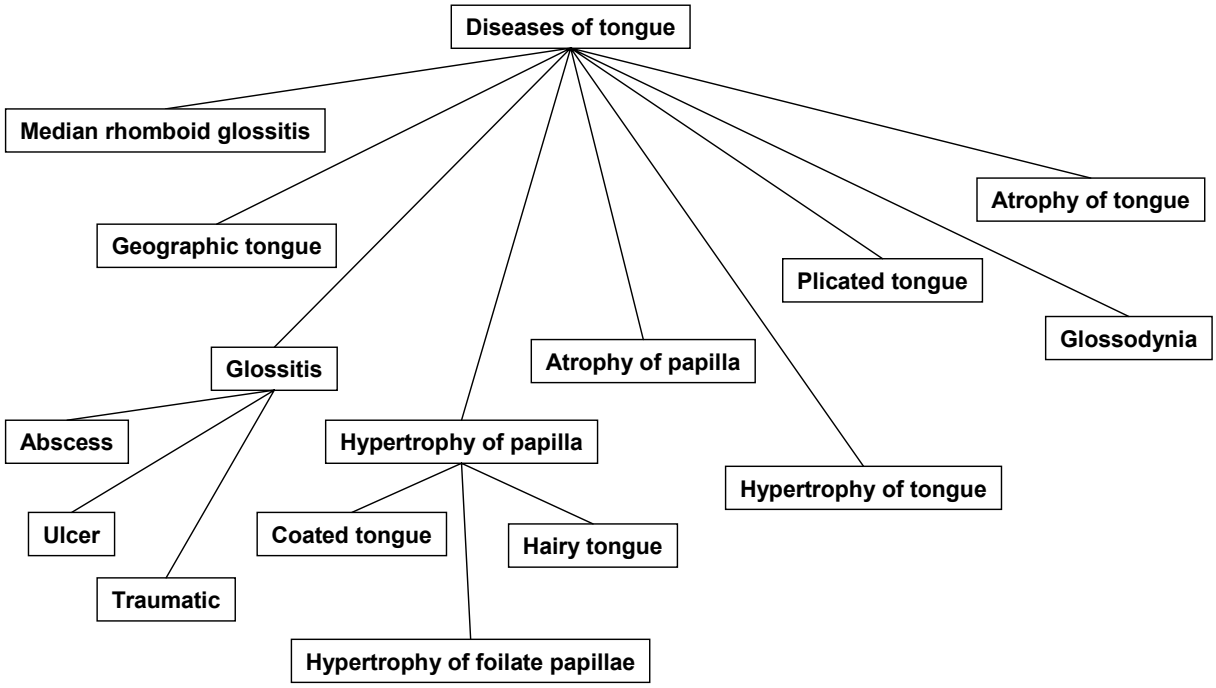

Fig. 11. The hierarchy of diseases of tongue

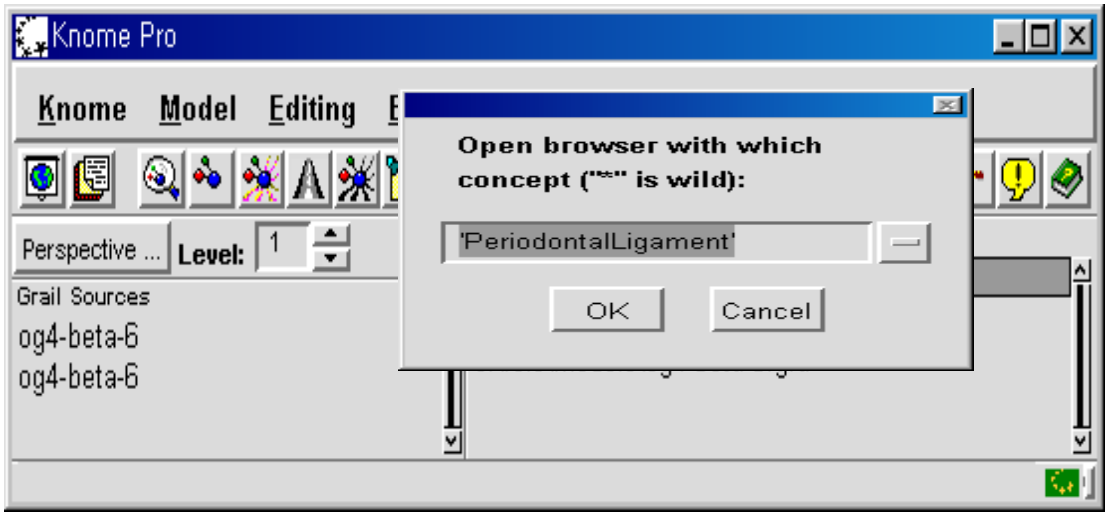

Fig. 12. Browsing of periodontal ligament

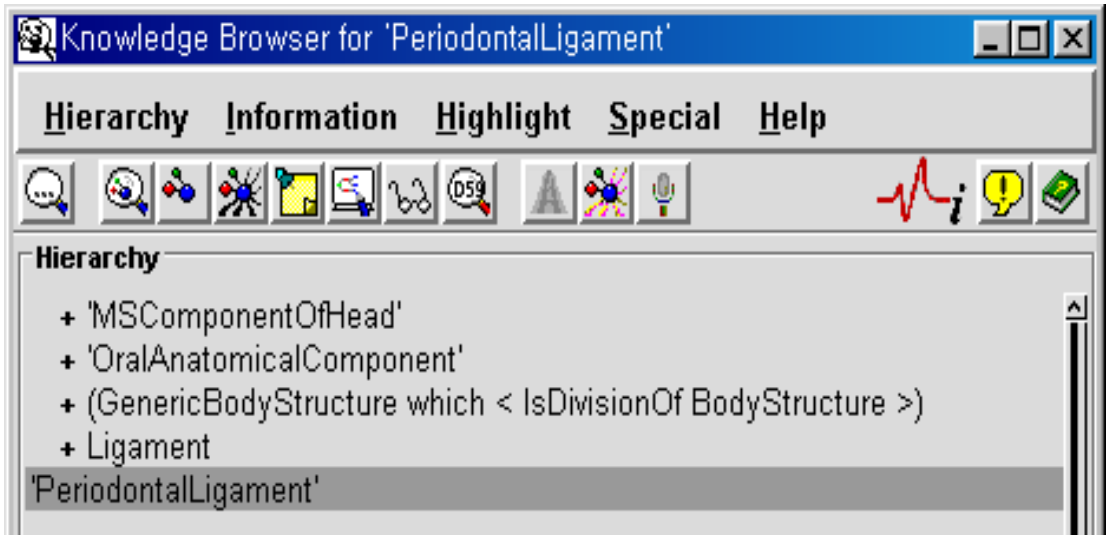

Fig. 13. Answer to the query of periodontal ligament

classified, based on their additional criteria and the multiaxial subsumption network was built automatically. All answers were correct on the basis of common dental knowledges that involve the constructed model. And it was possible to perform various levels of queries related to dental concepts.

Fig. 12 and Fig. 13 represent the browsing procedure of 'periodontal ligament'.

Ⅳ. DISCUSSION

The criteria for evaluating standardized coding and classification has been suggested by many researchers in medical and nursing terminologies.[14,26,27] The following properties are generally considered as appropriate in medical and nursing terminologies.[2,4,26,27]

- Completeness : The representation should be include all terms describing the clinical domain and should be broad enough to be applicable in a variety of settings.
- Coherence : The representation should be consistent with a clearly defined framework. Relationships among concepts should be explicit and it should be possible to classify concepts along multiple axes.
- Clarity : Concepts within the representation should have clear, understandable definitions.
- Expressiveness : The representation should be clinically expressive through the modification of concepts.
- Usefulness : The representation should be useful in clinical practice.
- Maintainability : The representation should be maintainable.

With reference to these properties, the dental concept model using GRAIL was made and evaluated. In addition, several specific considerations, related to unique characteristics of dentistry, could be reflected on formulation and evaluation of the dental concept model.

First, the more detailed expression may be needed for describing the anatomical structures in oral and maxillofacial region, compared to other body structures. These detailed expressions of oral and maxillofacial anatomy and diseases will be essential to apply the dental concept model to various clinical procedures of dentistry. For example, posterior occlusal tooth surface is composed of many elementary structures including pits, fossae, grooves, ridges, margins and etc.

Second, oral cavity contains many small structures, compared to other body structures. Therefore, it is difficult to define positional relations among anatomical structures in oral cavity. It may be necessary to develop new attributes suitable for description in dentistry. In the present study, only existing attributes, used in medical and nursing terminology, were applied and evaluated in the dental concept model.

1. General consideration

The important step in developing a GRAIL model is to decide what elementary entities there are and which entities are kinds of other entities.[2] The nodes in the hierarchies of dental concepts represent all of the entities used in dental concept modeling. The degree of specification of a category must be modelled explicitly in GRAIL. Different applications will require different degrees of specification.[2]

2. Modeling of anatomical structures in oral and maxillofacial region

(1) The modeling of tooth

1) The hierarchy of tooth

Adult teeth were classified under three criteria (anatomical shape of tooth, anatomical position of tooth in oral cavity, physiological function of tooth). In the present study, milk teeth were not modeled. But, it was necessary to formulate the concept model of them and it was expected that deciduous teeth would be modeled in the future.[28] The hierarchy of tooth can be added or corrected, according to various clinical requirements. For periodontic treatments, involved teeth can be pointed by the groups indicating six sections of dental arches, like maxillary upper molar region, lower anterior teeth region, etc.

2) Redefinition of Upper/LowerTooth

In the established GALEN CORE model, upper tooth was defined as a structural component of alveolar part of maxilla. But, this definition might not be commonly accepted in dentistry.[24,25] Upper tooth is thought to be an individual structure and is located in alveolar socket of alveolar bone.[28] both anatomic structures are linked by periodontal ligament. 'hasProximity' was thought be the most appropriate attribute which could describe the relationship between maxilla and upper tooth.

3) Parts which constitute tooth

There are so many components that make up tooth and each of them can be divided more minutely and variously.[25] Each part, which constitutes tooth, can be further divided, according to the requirements of clinicians or modelers. Because we first aimed to evaluate the constructed dental concept model for application in computer-based dental patient records, various components of tooth could be classified under three aspects (substance, solid structure and surface). Generally, these three aspects can be thought to be important and useful for describing patients' intraoral conditions.

(2) The modeling of periodontium

1) The modeling of cementum

Cementum is generally considered as one of the elements in periodontium,[28] while 'caries of cementum' is defined in ICD-DA.[19] So, it is rational that cementum be considered both one of the components of tooth and one of the elements in periodontium. In the constructed dental concept model, cementum could be browsed as a part of tooth, or a part of periodontium.

3. Modeling of diseases in oral and maxillofacial region

(1) Pathological and normal

The GRAIL model of oral and maxillofacial diseases was constructed mainly on elements of the schemata already mentioned in the anatomy model. An additional scheme, central to the notion of disease, is based on the distinctions between physiological and pathological, and between normal and nonNormal.[8,11] hasPathologicalStatus was a mainly used attribute in model of oral and maxillofacial diseases.

For example, Dental caries is described as follows.

(BodyStructure whichG <hasUniqueAssociated Process
(Demineralization which actsSpecificallyOn DentalHardTissue)
hasPathologicalStatus pathological
hasSpecificLocation ToothPart>)
name DentalCariesOfTooth

4. Problems in using GRAIL in dental concept modeling

In the dental concept model, most of the dental concepts could be described as sufficiently. But, it is not sufficient to describe some specific spaces in oral cavity, including interproximal spaces, gingival sulcus, and some specific surfaces such as occlusal surfaces and incisal edges. The relationship between dental calculus and surface of tooth is also difficult to describe using GRAIL. The attributes used for defining oral spaces, boundSpace and hasProximity, were thought to have some limitation to describe more detailed expressions. And, layered components such as enamel, dentin, cementum, and pulp could not be identified with any attributes in the model. There were also some difficulties in expressing states of progress in oral and maxillofacial diseases. In order to solve such difficulties, some more sophisticated attributes have to be devised so sufficiently as to represent location relationships with components in the mouth.

5. Evaluation of the constructed model

Automatic classification of dental concepts and re-usable language system are important characteristics of GRAIL and GALEN CORE model.[3,8] With reference to these two main characteristics, evaluation of the formulated model was performed. On the basis of the results in the present study, the formulated dental concept model could be believed to have the same characteristics of the established GALEN CORE model. And it was inferred that GRAIL and GALEN CORE model could be considered as suitable for application in dentistry, especially application in computer- based dental patient records.

In addition, the formulated dental concept model could work as a basis on the development of technologies for classification and coding systems, decision supporting systems and knowledge management systems in dentistry.

V. CONCLUSIONS

Our small-scale experiment has demonstrated that there is plausible evidence to suggest that a GRAIL model of dental terminology has the potential to apply in dentistry.

The obtained results were as follows.

1. From the results of review of the 150 patients' dental records, the dental terms that were primarily necessary to modeling, were as follows. In the category of anatomical structures, tooth was used most frequently, followed by gingiva, temporomandibular joint, lip, jaw, and tongue. And dental caries was used most frequently in the category of oral and maxillofacial diseases, followed by periodontitis, gingivitis, temporomandibular disorders, impaction of wisdom tooth, and cervical abrasion of tooth.
2. From the results of GRAIL modeling of tooth, periodontium, oral mucous membrane, tongue, lip, dental caries, pulpal and periapical diseases, diseases of periodontium, and diseases of oral mucous membrane, lip and tongue, it was inferred that most of the dental concepts were well expressed using GRAIL. However, it was not sufficient to describe some specific spaces and surfaces in oral cavity. There were also some difficulties in expressing states of progress in oral and maxillofacial diseases.
3. All entities in the model were subsequently classified and the multiaxial subsumption network was built automatically. And it was possible to perform various levels of queries related to dental concepts.

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국문초록

GRAIL을 이용한 치의학 용어 체계의 평가

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본 연구는, 기존의 나열식 분류체계의 문제점을 극복할 수 있는 GRAIL을 이용하여 두경부의 해부학적 구조물들 및 구강 악안면 영역의 주요 질병들과 관련된 치의학 개념들의 모델을 구축한 뒤, 완성된 치의학 개념 모델이 두경부의 해부학적 구조물들 및 구강 악안면 영역의 주요 질병들을 잘 표현할 수 있는지와 기존의 GRAIL 모델이 지닌 특징에 잘 부합하는지를 평가하고자 시행되었다. 서울대학교 치과병원 내원 환자 중 포괄적인 치과 치료 병력을 지닌 환자 150명의 치과 의무기록을 내용별로 분석하고, 각종 치의학 교과서와 기존의 의학용어 분류체계에서도 모델 구축에 필요한 치의학 용어를 선택하였다. 이들 자료를 바탕으로, GRAIL 모델 구축을 진행하고 구축된 모델을 평가할 수 있는 소프트웨어 프로그램인 'KnoME'에서 치의학 개념 모델을 구축하고 평가하여, 다음과 같은 결론을 얻었다.

1. 환자 150명의 치과 의무기록을 내용별로 분석한 결과, 우선적으로 모델 구축이 필요한 치의학 용어로는, 해부학적 구조물의 경우 치아, 치은, 악관절, 입술, 턱, 혀 등의 순서로 나타났으며, 구강악안면 영역의 병소에서는 치아 우식증, 치주염, 치은염, 악관절 장애, 매복 지치, 치경부 마모 등의 순서로 나타났다.
2. GRAIL을 이용하여 치아, 치주조직, 구강점막조직, 치아 우식증, 치수 및 치근단 병소, 치주질환, 구강점막질환의 모델 구축을 시행한 결과, 치의학 개념간의 다양한 관계가 대다수 잘 표현되었다. 그러나, 구강 악안면 영역의 해부학적 구조물에 대한 공간 정의의 한계성과 구강 악안면 질환의 진행 양상에 있어서 표현의 어려움이 관찰되었다. 이러한 부분은 GRAIL을 치의학 분야에 적용할 때, 극복해야 할 한계로 나타났다.
3. 치의학 개념들에 관한 다양한 질의를 시행한 후 그 응답 내용을 평가한 결과, 완성된 모델 내에서 치의학 개념의 자동적인 분류가 이루어 졌으며, 다양한 목적의 검색이 가능하였다. 이와 같은 사실로 미루어 보아서, 완성된 모델은 기존의 GRAIL 모델의 특성에 잘 부합되는 것으로 생각되었다.

주요어 : 치의학 용어, 모델 구축, GRAIL (GALEN Representation and Integration Language), KnoME (Knowledge Modeling Environment)