THE DISLODGEMENT OF THE SPONGE HEAD OF NOVEL THAI-PRODUCED SPONGE BRUSHES

จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

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A Thesis Submitted in Partial Fulfillment of the Requirements
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การศึกษาการหลุดของหัวแปรงฟองน้ำที่ผลิตใหม่ในประเทศไทย

น.ส.นวฉัตร มีชำนะ

จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
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วัตถุประสงค์หลักของงานวิจัยนี้คือ เปรียบเทียบการหลุดของหัวแปรงฟองน้ำที่ผลิตจากแหล่งต่างๆ โดยกลุ่มควบคุมใช้แปรงฟองน้ำของบริษัทบัตเลอร์นำเข้าจากประเทศญี่ปุ่น ส่วนกลุ่มทดลองเป็นแปรงฟองน้ำที่ผลิตขึ้นครั้งแรกในประเทศไทย โดยฟองน้ำมีลักษณะ 2 แบบ คือ แบบเนื้อนุ่มและแบบเนื้อแน่น แต่ละแบบมี 2 รูปร่าง คือ หน้าตัดรูปกลมและหน้าตัดรูปดอกลีลาวดี สำหรับวิธีการทดลองเริ่มแรกให้ตรวจสอบชนิดของพอลิออลจากฟองน้ำทั้ง 3 แบบ ด้วยเทคนิคอินฟราเรดสเปกโตรสโกปี เมื่อผลการวิเคราะห์แสดงลักษณะโพลีออลเป็นชนิดโพลียูรีเทนทั้งหมด จึงหาความหนาแน่นของฟองน้ำแต่ละชนิดจากการแทนค่าสมการ คือมวลหารด้วยปริมาตร ซึ่งปริมาตรสามารถวิเคราะห์ได้จากเครื่องเอกซเรย์คอมพิวเตอร์ระดับไมโครเมตร ส่วนการเปรียบเทียบการหลุดของหัวแปรงฟองน้ำ (30 ตัวอย่างต่อกลุ่ม) สามารถวิเคราะห์ได้จากค่าแรงที่ใช้ดึงหลุดหารด้วยความหนาแน่นของฟองน้ำชนิดนั้น โดยค่าแรงที่ใช้ดึงหลุดมาจากการทดสอบการดึงหัวแปรงฟองน้ำด้วยเครื่องทดสอบยูนิเวอร์แซลตามมาตรฐานสากล (ISO 20126:2012(E)) ผลการทดสอบพบว่าความหนาแน่นของฟองน้ำสีเหลืองที่ผลิตในประเทศไทย, ฟองน้ำสีขาวที่ผลิตในประเทศไทย และฟองน้ำที่ผลิตในประเทศญี่ปุ่น มีค่า 28.56, 16.17 และ 48.53 kg m^{-3} ตามลำดับ เมื่อเปรียบเทียบการดึงหัวแปรงฟองน้ำในกลุ่มที่ความหนาแน่นของฟองน้ำต่างกันพบว่าหัวแปรงฟองน้ำของบริษัทบัตเลอร์ต้านทานการหลุดได้ดีที่สุดรองลงมาคือหัวแปรงฟองน้ำสีเหลือง และหัวแปรงฟองน้ำสีขาวตามลำดับอย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05 เมื่อเปรียบเทียบการดึงหัวแปรงฟองน้ำในกลุ่มที่มีความหนาแน่นของฟองน้ำเท่ากัน พบว่าหน้าตัดรูปร่างกลมต้านทานการหลุดได้ดีกว่าหน้าตัดรูปร่างดอกลีลาวดีอย่างมีนัยสำคัญทางสถิติที่ระดับ 0.05 จากการวิเคราะห์ทางการทดลองเหล่านี้สนับสนุนว่าหัวแปรงฟองน้ำที่ผลิตจากฟองน้ำที่มีความหนาแน่นสูงต่อต้านการดึงหลุดได้ดีกว่าหัวแปรงฟองน้ำที่ผลิตจากฟองน้ำที่มีความหนาแน่นต่ำกว่า เนื่องจากฟองน้ำที่มีความหนาแน่นสูงมีคุณสมบัติทางกายภาพที่ดีกว่าฟองน้ำที่มีความหนาแน่นต่ำ ดังนั้นสำหรับการผลิตแปรงฟองน้ำในประเทศไทย จากผลการทดลองจะเห็นว่าแปรงฟองน้ำหน้าตัดรูปกลมสีเหลืองต้านทานการดึงหลุดได้ดีที่สุด แต่อย่างไรก็ดีควรมีการทดสอบตามมาตรฐานสากลในหัวข้ออื่นๆ เช่น การทดสอบความล้า และการทดสอบความสามารถในการรับแรงกระแทกของด้ามจับ นอกจากนั้นควรมีการทดสอบอันตรายทางชีวภาพอีกด้วย

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KEYWORD: Sponge brush Oral hygiene care Dislodgement of sponge head

Nawachat Meechumna : THE DISLODGEMENT OF THE SPONGE HEAD OF NOVEL THAI-PRODUCED SPONGE BRUSHES. Advisor: Asst. Prof. ORAPIN KOMIN, D.D.S., Ph.D. Co-advisor: Assoc. Prof. ATIPHAN PIMKHAOKHAM, D.D.S., Ph.D.

Objective. To perform an in vitro investigation on the dislodgement of sponge head of different manufactured sponge brushes (Sakura shape, Sunstar BUTLER, Japan, and 4 novel Thai-produced sponge brushes; combination of two shapes (round and Leelawadee) and two textures (soft and hard), King Dental Innovation Foundation; KDIF , Thailand. Methods. In order to evaluate the dislodgement of sponge head, strength test measurement was performed according to ISO 20126:2012(E). Five types of polyurethane foam were characterized using Fourier transform infrared spectroscopy (FTIR). The density of the foam was evaluated as the weight of foam in the air per unit volume of a specimen. Specimens were weighed. The volume was analyzed by Micro-CT. Finally, the mean “Force (N)/Density (kg/m^3)” data of each group was calculated and investigated. Results. The density of Thai-produced yellow foam, Thai-produced white foam and Japan-produced are as followings; 28.56, 16.17 and 48.53 kg m^{-3} respectively. The “Force/Density” value of each group were calculated. The comparative analysis revealed that the five types of sponge-foam have different densities. Sakura shape sponge head exhibited significantly more difficult to be dislodged, comparing to other four sponge heads. With the same density, round shape exhibited significantly more difficult to be dislodged, comparing to the Leelawadee shape. Conclusion. The yellow sponge head in the cross-section round shape had the most resistance to dislodgement, compared to four novel Thai-produced sponge brushes because of the higher density of foam results in the higher strength. By the way, fatigue resistance and handle impact test should be conducted for assessing the physical properties of handles. Biological hazards should be the greatest concern to assessing possible biological hazards.

Field of Study:	Geriatric Dentistry and Special Patients Care	Student's Signature ....
Academic Year:	2018	Advisor's Signature ....
		Co-advisor's Signature ....

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Nawachat Meechumna

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University

TABLE OF CONTENTS

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University

จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

LIST OF TABLES

จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

LIST OF FIGURES

Page

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University

CHAPTER 1

INTRODUCTION

Background and Rationale

Prevention of aspiration pneumonia by oral hygiene care is costless and fully effective. The systematic review was published in 2011. A summary of literature contributed since 2000 to 2009 indicated that the poor oral hygiene was the risk factor of aspiration pneumonia in frail elderly[1]. Therefore, oral hygiene care including tooth brushing after each meal, cleaning dentures once a day, and professional oral health care once a week is necessary to reduce the incidence of aspiration pneumonia[2]. The adequate oral hygiene care diminishes the risk of aspiration pneumonia by reducing of potential respiratory pathogens[3] and improving the swallowing reflex and cough reflex sensitivity[4, 5]. The randomized controlled trials of Yoneyama *et al.*[6] is one of those high methodological quality. They studied oral hygiene care and the incidence of pneumonia in 417 institutionalized the elderly. Intervention group was cleaned by toothbrush after each meal and professional care once a week. Povidone iodine was used in some cases. Control group cleaned themselves. In both groups dentures were clean. The result showed statistically significantly higher incidences of febrile days (RR = 2.45 and 95% CI = 1.77-3.40),

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University

pneumonia (RR = 1.67 and 95% CI = 1.01- 2.75), and dying from pneumonia (RR = 2.40 and 95% CI = 1.54-3.74), in the control group when compared to the intervention group. Interestingly, oral hygiene care was not only tooth brushing and denture cleaning but also the oral soft tissues cleaning performed in the palatal, mandibular mucosa and the tongue dorsum. All of these were suggested to maintain oral health.

Oral soft tissue cleaning in dependent patients is difficult because of its niches and patients' position. Providing oral hygiene care by caregivers to these patients is not easy to reach all areas of the mouth. Many patients may have consistent bleeding owing to systemic disease. Moreover, the age-related changes of oral mucosa have effect on their strength[7, 8]. Too hard nylon-bristle toothbrushes are not suitable. In Japan, caregivers always use sponge brush for swabbing oral mucosa. Oral mucosa cleaning is the components of the systematic oral care program for community-dwelling dependent and institutionalized elders[9, 10]. Sponge brush is the one of oral hygiene instruments. It has been used in hospital since 1970[11]. The sponge brush is a device utilized sponge for oral cleaning. It made of a piece of polyurethane foam which attached to the end of its handle. Preferably, the soft sponge facilitates gentle contact without trauma. It can be use to remove viscous fluid and food debris from oral recesses. However there have been many incidences in Wales, the report of dislodgement and tearing of sponge head resulted in pieces of sponge being retained in the oral cavity. These can be choking hazardously. It was finally withdrawn from Wales in 2012[12]. Meanwhile in Japan, no incidences was reported, they apply oral moisturizing gel to oral cavity for softening hard secretion before brushing with toothbrush and mucosa cleaning with sponge brush[10]. On the other hand, in Wales, where have been many incidents, they used sponge brush to clean teeth and soaked it in water before using. There are different usage characteristics, consequently, it is difficult to produce evidence-based conclusion.

In Thailand, the sponge brush will be the first produced for decreasing the importations from Japan. By the way, there is no product safety and efficiency standards. From the previous issues being discussed in Wales, we are interested in studying about sponge brushes that are manufactured in Thailand in terms of dislodgement of sponge head compared to Japan commercial products.

Research question

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Do different novel Thai-produced sponge brushes have significant different in dislodgement of sponge head?

Objective of the study

To perform an in vitro investigation on the dislodgement of sponge head of different novel Thai-produced sponge brushes (four novel Thai-produced sponge brushes; combination of two shapes (round and Leelawadee) and two textures (soft and hard), King Dental Innovation Foundation; KDIF, Thailand).

Statement of hypotheses

Null hypotheses

There is no significant difference in the dislodgement of sponge head when using different novel Thai-produced sponge brushes.

Alternative hypotheses

There is significant difference in the dislodgement of sponge head when using different novel Thai-produced sponge brushes.

Conceptual framework

จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

Independent variables

1. Novel Thai-produce sponge brushes
    1.1 White sponge head with round shape in cross-section
    1.2 White sponge head with Leelawadee shape in cross-section
    1.3 Yellow sponge head with round shape in cross-section
    1.4 Yellow sponge head with Leelawadee shape in cross-section

2. Japan sponge brush manufacturers

2.1 Sponge head with Sakura-shaped in cross-section

Dependent variable

Dislodgement of sponge head

Research design

Experimental design

Scope of the study

This present study was performed in the laboratory setting to investigate the dislodgement of sponge head by strength testing when using two manufacturer products. At the present time, according to lack of product safety standard, researcher adapted from ISO 20126:2012(E)[13].

Moreover, the results of this study may not be able to be extrapolated to other brand of sponge brush because the different brands have different properties.

Study limitation

Due to limited budget, all brands of sponge brushes cannot be tested. Thus, the brand which is commercial product in Japan was chosen to be the controlled in this study.

Keywords

Sponge brush, Oral hygiene care, Dislodgement of sponge head

The expected benefits

The results of this study might draw a clinical suggestion and information for proper usage of sponge brush and the results will be beneficial for further study.

CHAPTER 2

LITERATURE REVIEW

Aspiration pneumonia

Aspiration pneumonia are clinical syndromes that significant high morbidity and mortality, which is caused by aspiration of oropharyngeal or upper gastrointestinal contents in large volume into the lungs. Clinically condition is generally acute lung infection from the colonization of respiratory pathogens. The pathophysiology of aspiration pneumonia indicated that oropharyngeal colonization of potentially pathogenic organisms and macroaspiration was a key mechanism leading to acute pulmonary inflammation[14, 15]. A systematic literature review identified risk factors for aspiration pneumonia. A significant risk factor had been found was dysphagia[1, 15-17]. It associated with neurological disorders. The causes of neurogenic dysphagia include dementia, Parkinson’s disease, multiple sclerosis, and stroke. Moreover, chronic obstructive pulmonary disease that occurs in post-stroke patients is also risk factor because of laryngeal elevation impairment[18]. Similarly, oral hygiene is undoubtedly one of risk factors. Many studies have suggested that poor oral hygiene were associated with the occurrence of pneumonia. Terpenning *et al.*[19] reported dental decay, presence of cariogenic bacteria, and periodontal pathogens as significant risk factors. These associated with aspiration pneumonia. In the same way, Koichiro[20] studied oral cavities of aspiration pneumonia patients and found characteristics of poor oral hygiene such as mucous membrane residuals, coated tongue, and remaining roots. These conditions promote bacterial colonization. One of high quality method is the randomized controlled trials of Yoneyama *et al.*[6]. They studied oral hygiene care and the incidence of pneumonia in 417 institutionalized elders. Intervention group was cleaned by toothbrush after each meal and professional care once a week. Povidone iodine was used in some cases. Control group cleaned by themselves. In both groups, dentures were clean. The result showed statistically significantly higher incidences of febrile days (RR = 2.45 and 95% CI = 1.77-3.40), pneumonia (RR = 1.67 and 95% CI = 1.01-2.75), and dying from pneumonia (RR = 2.40 and 95% CI = 1.54-3.74), in the control group when compared to the intervention group. On the other hand, the edentulous patients and good oral hygiene patients have lower risk of aspiration pneumonia[21, 22]. Poor oral hygiene has been associated with an increased risk of aspiration pneumonia. Therefore, the adequate oral hygiene care diminishes the risk of aspiration pneumonia by reduction of potential respiratory pathogens[3] and improving the swallowing reflex and cough reflex sensitivity[4, 5]. Apart from dysphagia and oral hygiene, there are also other significant risk factors. Age, male gender, lung disease, diabetes mellitus, genotype, malnutrition, and drug are also concerned[1].

Oral hygiene care

Oral hygiene care is crucial for aspiration pneumonia prevention among hospitalized, institutionalized, or community-dwelling elderly. Because poor oral hygiene can induce oral pathogenic microorganism related to pneumonia,[23, 24] especially in institutionalized elderly[6]. Pneumonia greatly increases the risk of long-term morbidity and mortality[25]. It is associated with increased medical care costs[26]. In Australia, the current provision of oral health care consists of tooth brushing and cleaning the tongue, palate, gums and oral mucosa with a soft mechanical toothbrush suitable for bending, using high fluoride toothpaste (5000 ppm) and an interdental brush. The dentures are cleaned with a denture brush or a soft toothbrush suitable for bending[27]. In Japan, eating function are also considered as the current practice[20].

In community-dwelling elderly, who provide self-care practice, tooth brushing may improve arm-joint motion and muscle strength[28]. The Bass brushing method was effective evidence-based strategy [29] that reduced dental plaque in the elderly[30].

For institutionalized elderly, oral health programs were developed. These were based on systematic reviews and randomized control trials. The interventions are as follows:

1. Non-professional oral health care

The strategy was developed by educating caregivers. A randomized controlled trial assessed the effectiveness of a caregivers education program which will improve dental plaque indexes, denture plaque, denture-induced stomatitis and gingivitis. These intervention group's oral health scores were improved significantly[31].

2. Professional oral health care and non-professional oral health care

The systematic review and meta-analysis on the effect of oral care in the nonventilated patient population revealed that mechanical oral cleaning in combination with professional oral health care decreased the risk of death due to pneumonia[32].

3. Professional oral health care

A randomized controlled trial assessed the oral hygiene improvement rates in the relation to the frequency of professional oral health care intervention. The results showed that oral health improved by providing professional oral health care at intervals of one week for twelve consecutive weeks in short-term care and at intervals of two weeks for twenty consecutive weeks in mid-term care[33].

In dependent patients, oral mucosa cleaning is difficult because of patients' position. Providing oral hygiene care by caregivers to these patients is not easy to reach all areas of the mouth. Many patients may have consistent bleeding. Moreover, the age-related changes of oral mucosa has an effect on their strength[7, 8]. Oral mucosa of the elderly patients is generally thinner due to decrease and degradation of collagen fiber. Tissue repair occurs less than younger people[34]. These reasons compromise the oral tissue barrier so that pathogenic bacteria can easily adhere to epithelium cells by surface adhesion, leading to increased susceptibility to disease [35]. Furthermore, dry mouth usually occurred in the elderly. The prevalence of oral soft tissue dryness increases with age which affected approximately 30% of the elderly[36, 37] because of decreasing of flow rate, increasing of ionic concentration, and decreasing calcium and mucin in saliva[38]. In order to maintain oral health, reserving the oral cavity moist is very important. Oral moisturizing gel helps soothing and moisturizing. The moisturizing gel have hyaluronic acid, trehalose, and water content (75% or more). It is applied to oral cavity to soften hard secretions. In Japan, the protocol was concluded that oral moisturizing gel should be firstly applied. Afterward, the teeth were brush and then the tongue was cleaned. Finally swabbing with sponge brush and wiping with an oral care mouth wipe. The eating function is also improved by breathing and saliva swallowing practice[10].

Sponge brush

Sponge brush is the one of an oral hygiene instrument. It is a device utilized a sponge for oral cleaning. It made of a piece of foam attached to the end of its handle. It has been used in hospital since 1970[11]. Formerly, Sponge brush commonly used by nurses to provide oral hygiene care in the United Kingdom while toothbrush was not the tool of choice, especially in intensive care unit patients. Most intubated patients have an absence of mastication and patients develop pressure sores due to intubation. Nurses are preferably to use sponge brush because easy to manipulate[39]. In subsequent years many studies were done to prove the effectiveness of sponge brush in order to remove plaque[40-43]. Presently, there is strong evidence to support the use of a toothbrush as the most effective method for dental plaque removal and most commonly use for maintenance of oral hygiene care. Although the sponge brush was not suitable for brushing, it was recommended for the application of moisture to the oral cavity, especially in chemotherapy patients[44]. Preferably, the soft sponge facilitates gentle contact without trauma. In Japan, caregivers retained moisture in the oral cavity at the first step. They apply oral moisturizing gel for soften hard secretion with sponge brush and swab oral mucosa for removing crusts. The moisturizing gel make more easily removal and can extend the moisturizing effect[10, 20].

However there have been 113 relevant incidents in Wales[12], which occurred on after 1 April 2008. Most incidents were reported as resulting in no harm (n=108) and some in low harm (n=4). Only one incident involving a child was reported as resulting in moderate harm. Most reports describe that the dislodgement and tearing of sponge head resulted in pieces of sponge being retained in the mouth and/or entrance to the airway. These can be choking hazardously. Although, they suggested users “not to soak the sponge brush in liquid”. But the incidence still occurred. They believed that is not easy to distinguish between moist and soaking. After that, in 2012 sponge brushes for oral care were banned in Wales. Nevertheless, this not strong enough for certain conclusion. The most likely reason for dislodgement of sponge head is prolonged immersion in water. It seems like a mis-used. Whereas in Japan, where no incidents occurred, they apply oral moisturizing gel before usage[10]. Which corresponds to those of Yonezawa *et al*. who reported that sponge brush should not be wet to lower risks of aspiration[45].

Flexible polyurethane foam

2.1 An introduction to polyurethanes

The discovery of polyurethane (PUR) was originated by Otto Bayer and coworker in 1937. The polymer shown was formed by the step polymerization. The product of reaction is urethane linkage (–NH–(C = O)–O–). In the 1950, Polyurethane can be produced with fast rate of rigid or flexible polyurethane foam by the reaction of toluene diisocyanate (TDI) and polyether and polyester polyol[46]. With further development, it can be designed for specific purposes. Commercially, there are two forms of PUR foam: PUR foams and non-foam applications. Some example of non-foam products are coating, sealants, elastomers and adhesives[47].

2.2 Types of polyurethane foam

Thermoset PUR foam can be divided into mainly flexible and rigid PUR foams. Based on the basic chemistry, a summary of characteristics foam grades is illustrated in Table 1[46].

Table 1 Characteristics of PUR foam grades.

Characteristics	Flexible PUR foam	Rigid PUR foam
Polyols		
: Molecular weight	1,000 to 6,500	150 to 1,600
: Functionality range	2.0 to 3.0	3.0 to 8.0
: Hydroxyl value range (mg KOH/g)	28 to 160	250 to 1,000

Isocyanates	TDI based	MDI based
Density range (kg/m^3)	5 to 200	20 to 800
Property	Absorption	Insulation

In addition, PUR are defined by three categories of their stiffness and applications as Flexible polyurethane foam, Semi-rigid polyurethane foam and Rigid polyurethane foam. A summary of the category is illustrated in Table 2[48].

Table 2 Categories of PUR foam.

Polyol	Rigid foam	Semirigid Foam	Flexible foam
OH No.	350-560	100-200	5.6-7.0
OH Equivalent No.	160-100	560-280	10,000-800
Functionality	3.0-8.0	3.0-3.5	2.0-3.1

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Elastic Modulus at 23 degree C MPa Ib/in^2	>700 >100,000	700-70 100,000-10,000	<70 <10,000
Market	Insulation material	Elastic fiber	Car seats and auto-motive applications

In conclusion, this wide range of properties makes PUR an essential material in furniture, automotive part, construction, and appliance [46].

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2.3 Raw materials for flexible polyurethane foam formation [48]

2.3.1 Isocyanates

Isocyanates are compounds containing the reactive group (-NCO). There are basically three types of isocyanate compounds: aliphatic, cyclo-aliphatic, and aromatic isocyanates. Approximately 95% of PUR foam consists of aromatic isocyanates. There are toluene diisocyanate (TDI), methylene diphenyl diisocyanate (MDI) and polymeric products (PMDI). Toluene diisocyanate is primarily used as a chemical intermediate in the production of polyurethane products. There are two main types of isomers: 2, 4-TDI and 2, 6-TDI which is commercially supplied as the weight ratio of 80:20. Structures of TDI are presented in figure 1 below:

(a) 2, 4 – TDI (b) 2, 6 – TDI

Figure 1 - (a) Structures of 2, 4- toluene diisocyanate (TDI) isomers; (b) structures of 2, 6- toluene diisocyanate (TDI) isomers.

The second most important aromatic isocyanates is methylene diphenyl diisocyanate (MDI). There are two available types of commercial products: pure MDI and crude MDI. The main applications for pure MDI are elastomers and some flexible foam. Crude MDI is used for rigid and semi-rigid PUR foam the predominant isomer in commercial PUR foam is 4, 4-MDI. Structures of MDI are presented in figure 2 below:

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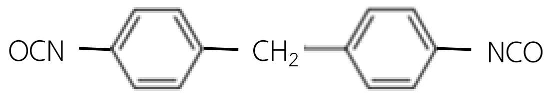
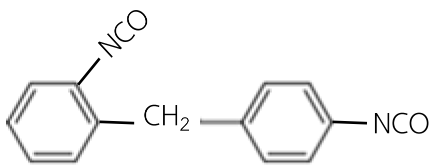
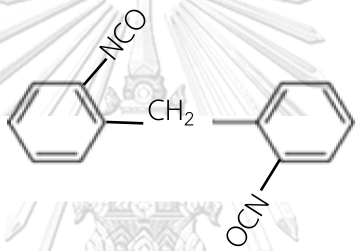


(a) 4, 4- MDI



(b) 2, 4- MDI



(c) 2, 2- MDI

Figure 2 - (a) Structures of 4,4- methylene diphenyl diisocyanate (MDI) isomers; (b) structures of 2,4- methylene diphenyl diisocyanate (MDI) isomers; (c) structures of 2,2-methylene diphenyl diisocyanate (MDI) isomers.

2.3.2 Polyol

The important based polyols are used for flexible polyurethane foam is polyether containing two or more hydroxyl group with terminal chain and other compounds such as polyesters, hydroxyl terminated polyolefin, and hydroxyl containing vegetable oils. The properties of PUR depend on the selection of polyols; therefore, molecular weight, functionality, hydroxyl (OH) number have to be selected. Several hydroxyl group with short chain structure making high cross-linked polymer contributes to an increase in the stiffness properties. Due to these characteristics flexible PUR foam has lower cross-linked polymer than rigid PUR foam.

2.3.3 Blowing agent

A blowing agent plays an important role to form gas bubbles in polymerization. The conventional blowing agent is water which is reacted with isocyanates producing carbon dioxide. Carbon dioxide is produced by polymerization and the polyurea is also formed. Foam expansion process is produced by carbon dioxide but the urea linkage resulting in mechanical properties.

2.3.4 Catalysts

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Several types of catalysts such as aliphatic and aromatic tertiary amines and organo-metallic compound are used. Catalysts can be classified into three main categories according to the reaction purposed: Blowing catalysts, Gelling catalysts, and Trimerization catalysts.[16] The most used catalysts in flexible polyurethane foam production is tertiary amine.

2.3.5 Surfactants

The function of surfactant is to assist the incompatible foaming ingredients in the mixing step, controlling surface tension, and foam cell stabilizer in the polymer matrix. Silicone surfactants are mostly used in PUR foam.

2.3.6 Cross-linker

Reactive group of cross-linking agents are glycol, diamine, and hydroxyl amine when reacting with diisocyanate to form urethane and polyurethane. The purpose of cross-linking agent is to create a mechanical advantage.

2.3.7 Additives

Additives are used in PUR for many reasons, including to coloring materials, reduce flammability, and improve the performance.

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CHAPTER 3

MATERIALS AND METHODS

3.1 Materials

Sample description

3.1.1 Control group

The material used for control group is commercial sponge brush in Japan, Sakura-shaped in cross-section (Sunstar BUTLER, Japan) as a control group (Figure 3).

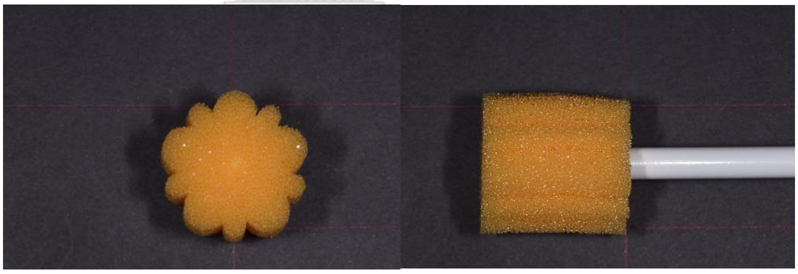

Figure 3 Sponge head with Sakura-shaped in cross-section.

3.1.2 Experimental groups

The experimental group (Figure 4-7) was the novel Thai-produced sponge brush. These can be classified into four sponge head types according to their shapes and colours: white sponge head with round shape in cross-section, white sponge head with Leelawadee shape in cross-section, yellow sponge head with round shape in cross-section, and yellow sponge head with Leelawadee shape in cross-section. For each group, 30 samples were evaluated with the same study protocol.

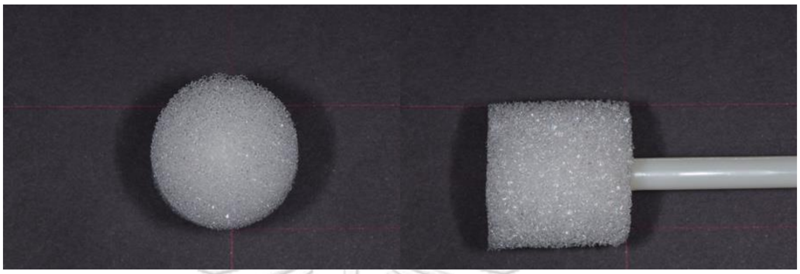

Figure 4 White sponge head with round shape in cross-section.

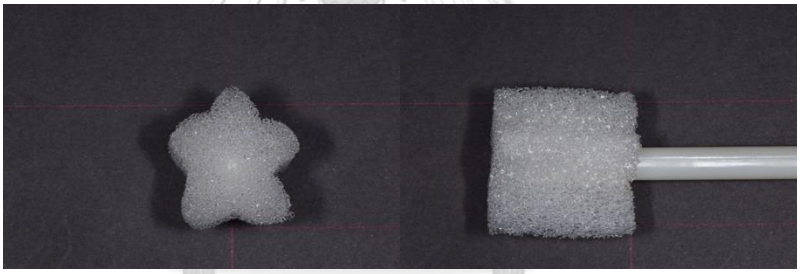

Figure 5 White sponge head with Leelawadee shape in cross-section.

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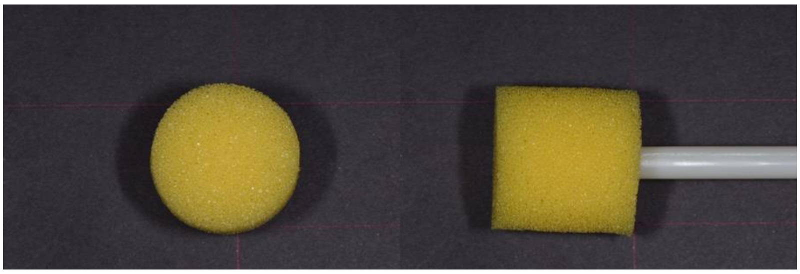

Figure 6 Yellow sponge head with round shape in cross-section.

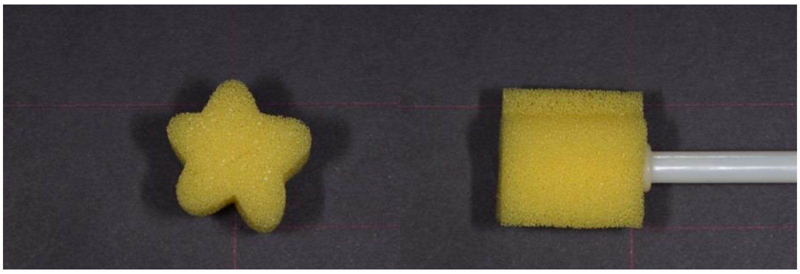

Figure 7 Yellow sponge head with Leelawadee shape in cross-section.

Detailed description

The disposable oral hygiene device is used to clean oral mucosa, remove viscous fluid and food debris from oral recesses. “Disposable” defined as being used once and not intended to be washed and reused. The advantage of using disposable sponge brushes is to prevent bacterial contamination. Sponge head is made from polyurethane polymers. Food grade polyurethane foam is used for sponge head manufacture. The handle of the sponge brushes are produced from acrylonitrile-butadiene-styrene resins. A summary of physical properties of polyurethane foam that used to produce the yellow sponge head and the white sponge head is illustrated in Table 3 and Table 4.

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Table 3 Physical properties of yellow polyurethane foam.

Test Items	Unit	Specification	Method
Density	kg/m^3	23±2	JIS K6400
Hardness	$kg/314/cm^2$	10±2	JIS K6401
Elongation	%	≥100	JIS K6400
Tensile Strength	kg/m^2	≥0.8	JIS K6400
Tear Strength	kg/cm	≥0.6	JIS K6400

Table 4 Physical properties of white polyurethane foam.

Test Items	Unit	Specification	Method
Density	kg/m^3	13.5±2	JIS K6400
Hardness	$kg/314/cm^2$	6.5±2	JIS K6401
Elongation	%	≥160	JIS K6400
Tensile Strength	kg/m^2	≥0.6	JIS K6400
Tear Strength	kg/cm	≥0.5	JIS K6400

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3.2 Equipments

3.2.1. Universal testing machine (EZ-S, SHIMADZU, Japan)

3.2.2. Test grips

3.2.3. Digital vernier caliper (Mitutoyo Corp., Kanogawa, Japan)

3.2.4. Scanning electron microscope (FEI Quanta 250, Thermo Scientific, Canada)

3.2.5. Digital balance (ATY224, SHIMADZU, Japan)

3.2.6. Micro-CT (SCANCO Medical, Switzerland)

3.2.7. Fourier transform infrared spectroscopy (Nicolet 6700, Thermo Scientific, United States)

3.3 Methods

Polyols characterization

3.3.1 Fourier transform infrared spectroscopy

The polyurethane characterization of foams were characterized using Fourier transform infrared spectroscopy (FTIR). These equipped with a Smart iTR diamond attenuated total reflectance (ATR) accessory operated at 4 cm^{-1} spectral resolution over the wavenumber range of 4000-650 cm^{-1}.

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Foam properties measurement

3.3.2 Density

The density of foams can be evaluate as the weight of foam in air per unit volume of specimen, after a part of spong head which is not cover the handle have been cut off. The test specimens are generally square shape with dimension of thickness = 3 mm, width = 5 mm., and length = 5 mm. The specimens is measured actual dimension using a vernier caliper and accurately weighed on a balance. The volume of test specimens were analyzed by Micro-CT (SCANCO Medical, Switzerland). After that, the densities were calculated according to the formula:

$$\text{Density (kg/m}^3\text{) = Sample weight (kg)/volume (m}^3\text{)}$$

3.3.3 The dislodgement of sponge head test

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In order to evaluate the dislodgement of sponge head, strength test measurement was performed by using a universal testing machine (EZ-S, SHIMADZU, Japan). Sponge brushes were tested in direct tension and performed in laboratory environment. Before testing, the complete assembly of the test grips were attached to the universal testing machine. Midline positioning was verified. The distance between the two grip surfaces were adjusted to about 20 cm (for pre-loading avoidance). The strength test was performed according to ISO 20126:2012(E)[13]. The machine was equipped with a load cell or force measuring device that can measure the maximum applied force. The test run at speed of 20 mm/min.

Sponge brushes were placed in the grips of testing machine, clamped down firmly on the excessive foam in the lower grip and the handle on the other side, carefully adjusted them symmetrically. In order that the dislodgement of sponge head was distributed uniformly over the cross section. The automatic recording device was started, it recorded the data continuously by reading the maximum load at time of dislodgement of sponge head as shown in Figure 8-9.

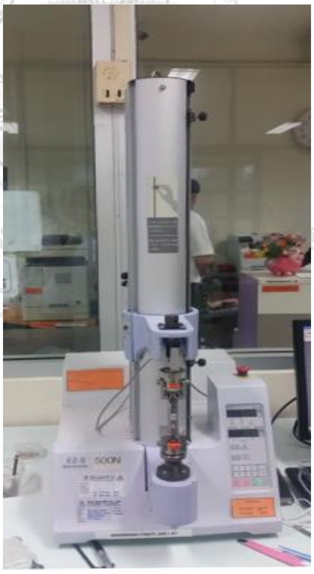

Figure 8 Universal testing machine (EZ-S, SHIMADZU, Japan).

Figure 9 The picture of sponge brush sample clamped in grip for dislodgement of sponge head test.

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3.3.4 Scanning electron microscope

The cellular structure of foams was observed using Scanning Electron Microscope (FEI Quanta 250, Thermo Scientific, Canada). The small portion of foams were cut and sliced carefully with sharp blade. The samples were sputter-coated with gold and stucked onto aluminum stubs before scanning under an accelerating voltage of 20 kV.

3.4 Data analysis

The "Force/Density" value of each group were calculated. To investigate the significant difference between the mean values of five sponge brushes, a parametric test, Levene static, and ANOVA were carried out. Multiple comparisons were performed by Bonferroni method. All tests were conducted with statistic significant set at α = 0.05 using SPSS version 17.0 (Chicago, IL, USA).

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CHAPTER 4

RESULTS

4.1 Fourier transform infrared spectroscopy of polyols

The ATR-IR spectroscopy was used for identification of the chemical reaction of the polyols formation and can presume the structural by comparing the peak position. Polyurethane functional groups were the similar characteristics. The results showed that all of sponge head made from polyurethane. The data is presented in Figure 10-12. These showed the Fourier transform infrared spectroscopy obtained from the test specimens from sponge head with Sakura-shaped in cross-section, white sponge head, and yellow sponge head, respectively. The absorption band at 3292, 3289, and 3290 cm^{-1} corresponds to NH stretching. The carbonyl stretching region was observed between 1650 and 1750 cm^{-1}. These were associated with functional groups in polyurethane[49].

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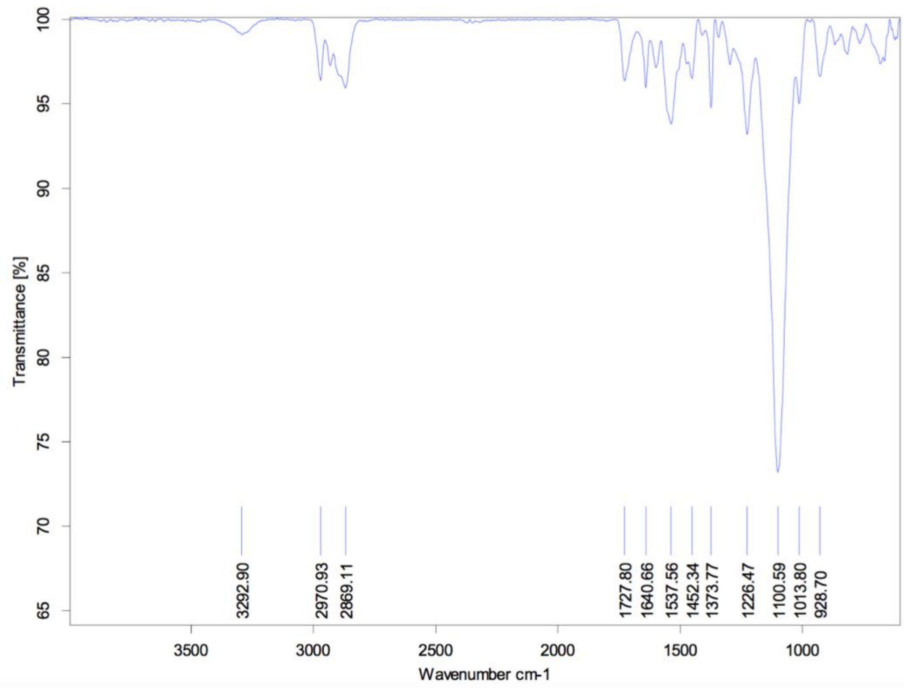

Figure 10 ATR-IR spectra of test specimen from sponge head with Sakura-shaped in cross-section.

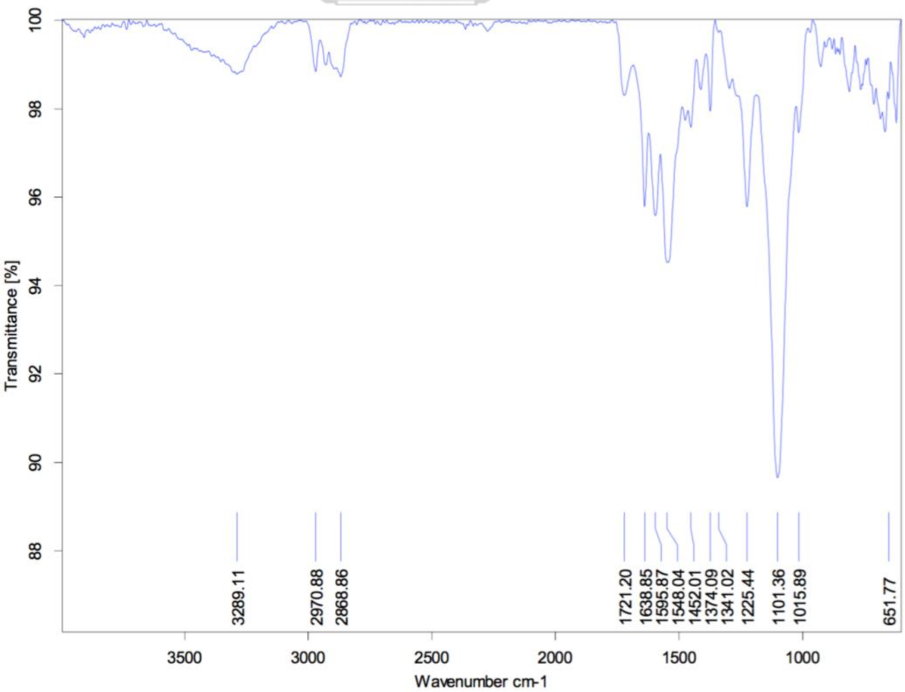

Figure 11 ATR-IR spectra of test specimen from white sponge head.

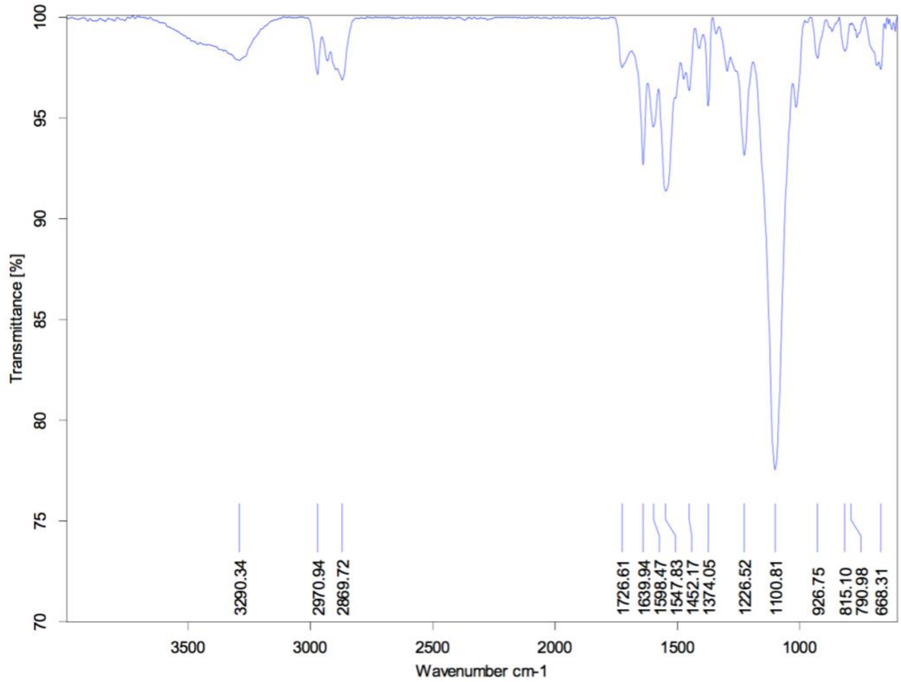

Figure 12 ATR-IR spectra of test specimen from yellow sponge head.

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4.2 The densities of different foams

The densities were calculated according to the formula:

Density (kg/m^3) = Sample weight (kg)/ volume (m^3)

The volume of test specimens were characterized using Micro-CT (SCANCO Medical, Switzerland). Each specimen was weighted on a balance. The average density value of each group were calculated. The results are summarized in Table 5. Considering the weight/volume value, the polyurethane foam from control group gave higher average density than the polyurethane foam from both experimental groups, when comparing between experimental groups which showed the polyurethane foam from yellow sponge head gave higher average density than the polyurethane foam from white sponge head. The analytical data from Micro-CT (SCANCO Medical, Switzerland) are shown in APPENDIX A (Figures A1-A9).

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Table 5 Average densities of different foams.

Group		Total volume (mm^3)	Weight (g)	Density (kg/m^3)
Test specimens from sponge head with Sakura-shaped in cross-section	No.1	189.5751	0.0094	49.58
	No.2	199.6633	0.0093	46.58
	No.3	200.3068	0.0099	49.42
	Average			48.53
Test specimens from white sponge head	No.1	308.9670	0.0050	16.18
	No.2	299.8324	0.0048	16.01
	No.3	306.1318	0.0050	16.33
	Average			16.17
Test specimens from yellow sponge head	No.1	246.3151	0.0068	27.61
	No.2	290.3680	0.0087	29.96
	No.3	227.6481	0.0064	28.11
	Average			28.56

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4.3 The dislodgement of sponge head of different manufactured sponge brushes

The dislodgement of sponge head test was mechanical test measuring the maximum of force load a sponge head can completely separate from handle. The data from these test was dislodgement force. These data was shown in APPENDIX B (Table B1-B5). After that, raw data was devided by their density. Consequently, “Force/Density” value from each group were compared the significant difference.

Statistical analysis was performed by utilizing the Shapiro-Wilk test for normality determination. In these results, the null hypothesis states that the data follow a normal distribution. Because the p-values is 0.173, which is greater than the significant level of 0.05, it is to fail to reject the null hypothesis. The results were shown in Table 6.

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Table 6 Tests of Normality.

Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Sponge head with Sakura-shaped in cross-section	0.167	30	0.033	0.950	30	0.173
White sponge head with Leelawadee shape in cross-section	0.134	30	0.177	0.943	30	0.107
Yellow sponge head with Leelaeadee shape in cross-section	0.110	30	0.200*	0.942	30	0.102
White sponge head with round shape in cross-section	0.129	30	0.200*	0.942	30	0.101

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Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
Yellow sponge head with round shape in cross-section	0.149	30	0.088	0.932	30	0.056

* This is a lower bound of the true significance.

a. Lilliefors Significance Correction

Statistical analysis was performed by utilizing the Levene statistic for determining a homogeneity of variance. In these results, the null hypothesis states that the conditions have about the same amounts of variability. Because the p-values is 0.146, which is greater than the significant level of 0.05, it is to fail to reject the null hypothesis. The results were shown Table 7.

Table 7 Test of Homogeneity of Variance.

	Levene tatistic	df1	df2	Sig.
Based on Mean	1.734	4	145	0.146
Based on Median	1.222	4	145	0.304
Based on Median and with adjusted df	1.222	4	122.774	0.305
Based on trimmed Mean	1.655	4	145	0.164

Statistical analysis was performed by utilizing the Anova statistic to test if two or more groups differ from each other significantly in one or more characteristics. In these results, the null hypothesis states that there are no a difference between groups. Because the p-values is 0.000, which is lesser than the significant level of 0.05, The null hypothesis is rejected. The results were shown Table 8.

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Table 8 ANOVA.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	3.359	4	0.840	796.406	0.000
Within Groups	0.153	145	0.001		
Total	3.512	149			

Comparison of dislodgement of sponge head from different manufacturers are shown in Table 9. In differrent densities, lower value of force/density (F/D) implied the higher resistance to dislodgement of sponge head, white sponge head exhibited significantly less difficulty in dislodging, compared with yellow sponge head and Sakura shape sponge head, respectively. On the other hand, in the same density, higher value of force/density (F/D) implied the higher resistance to dislodgement of sponge head, star shape exhibited significantly less difficulty in dislodging, compared with round shape.

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Table 9 Multiple Comparisons.

Dependent Variable: Force/Density

Bonferroni

Treatment		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
(I) Treatment	(J) Treatment				Lower Bound	Upper Bound
Sakura shape	White Leelawadee shape	-0.37164*	0.00838	0.000	-0.3955	-0.3477
	Yellow Leelawadee shape	-0.25813*	0.00838	0.000	-0.2820	-0.2342
	White round shape	-0.43549*	0.00838	0.000	-0.4594	-0.4116
	Yellow round shape	-0.30606*	0.00838	0.000	-0.3300	-0.2822

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Treatment		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
(I) treatment	(J) treatment				Lower Bound	Upper Bound
White Leelawadee shape	Sakura shape	0.37164*	0.00838	0.000	0.3477	0.3955
	Yellow Leelawadee shape	0.11351*	0.00838	0.000	0.0896	0.1374
	White round shape	-0.06385*	0.00838	0.000	-0.0878	-0.0400
	Yellow round shape	0.06558*	0.00838	0.000	0.0417	0.0895
Yellow Leelawadee shape	Sakura shape	0.25813*	0.00838	0.000	0.2342	0.2820
	White Leelawadee shape	-0.11351*	0.00838	0.000	-0.1374	-0.0896
	White round shape	-0.17736*	0.00838	0.000	-0.2013	-0.1535
	Yellow round shape	-0.04793*	0.00838	0.000	-0.0718	-0.0240

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Treatment		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
(I) treatment	(J) treatment				Lower Bound	Upper Bound
White round shape	Sakura shape	0.43549*	0.00838	0.000	0.4116	0.4594
	White Leelawadee shape	0.06385*	0.00838	0.000	0.0400	0.0878
	Yellow Leelawadee shape	0.17736*	0.00838	0.000	0.1535	0.2013
	Yellow round shape	0.12943*	0.00838	0.000	0.1055	0.1533
Yellow round shape	Sakura shape	0.30606*	0.00838	0.000	0.2822	0.3300
	White Leelawadee shape	-0.06558*	0.00838	0.000	-0.0895	-0.0417
	Yellow Leelawadee shape	0.04793*	0.00838	0.000	0.0240	0.0718
	White Round shape	-0.12943*	0.00838	0.000	-0.1533	-0.1055

*. The mean difference is significant at the 0.05 level.

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The characteristics of the dislodgement of sponge head were found in two types. One was total dislodgement of foam and the other was partial tear of foam. The type of dislodgement is presented in Figure 13-17. Yellow sponge head with both shapes in cross-section and white sponge head with round shape in cross-section had only total dislodgement of foam, however, other sponge heads presented two types of dislodgement. These data are showed in Table 10.

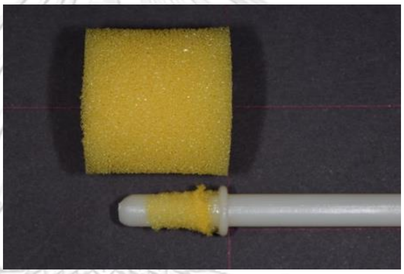

Figure 13 The yellow sponge head with round shape in cross-section showed a total dislodgement of foam.

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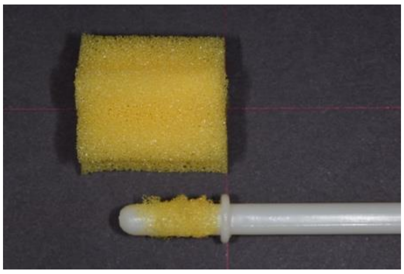

Figure 14 The yellow sponge head with Leelawadee shape in cross-section showed a total dislodgement of foam.

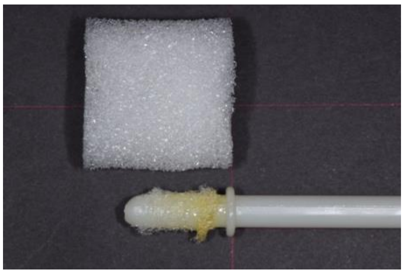

Figure 15 The white sponge head with round shape in cross-section showed a total dislodgement of foam.

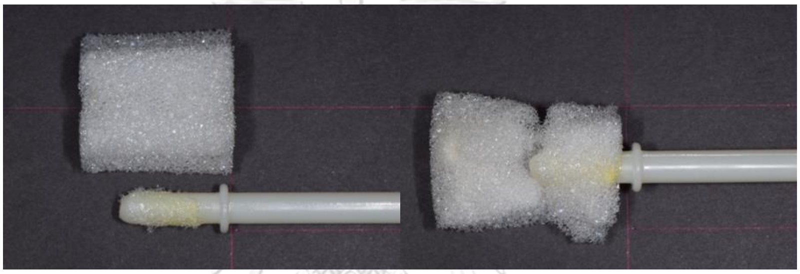

Figure 16 The white sponge head with Leelawadee shape in cross-section showed a total dislodgement of foam and partial tear of foam.

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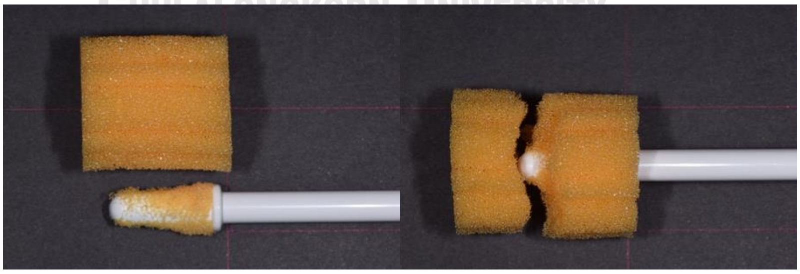

Figure 17 The sponge head with Sakura-shaped in cross-section showed a total dislodgement of foam and partial tear of foam.

Table 10 The characteristics of dislodgement of sponge head.

Group	Total dislodgement of foam (piece)	Partial tear of foam (piece)	Total (piece)
Sponge head with Sakura-shaped in cross-section	26	4	30
White sponge head with round shape in cross-section	30	0	30
White sponge head with Leelawadee shape in cross-section	26	4	30
Yellow sponge head with round shape in cross-section	30	0	30
Yellow sponge head with Leelawadee shape in cross-section	30	0	30

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4.4 Morphology of different foams

The SEM images of foam are shown in Figure 18-20. The structure of cell foams in the top of cross-section exhibited highly uniform and mostly opened-cells. The rupture of cell struts result from cutting samples. The foam cellular structure comprised of tetrakaidekahedral unit cells with struts and some thin cell window films.

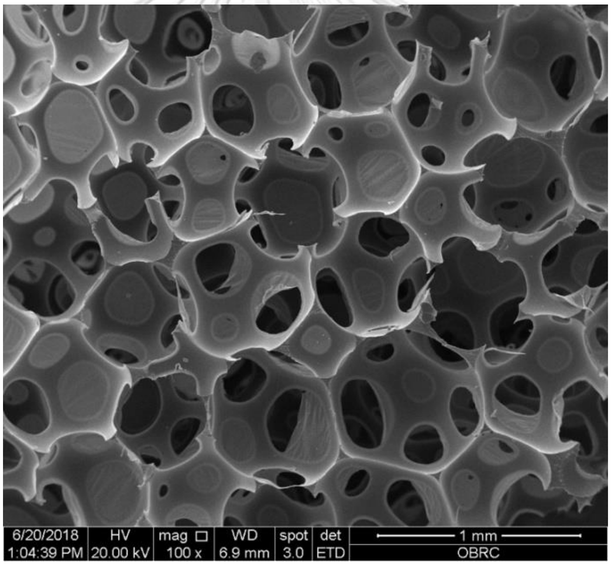

Figure 18 SEM micrographs of test specimen of sponge head with Sakura-shaped in cross-section.

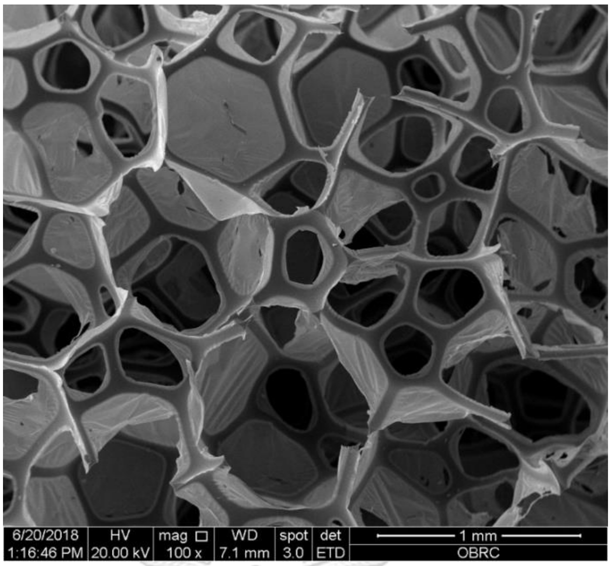

Figure 19 SEM micrographs of test specimen of white sponge head.

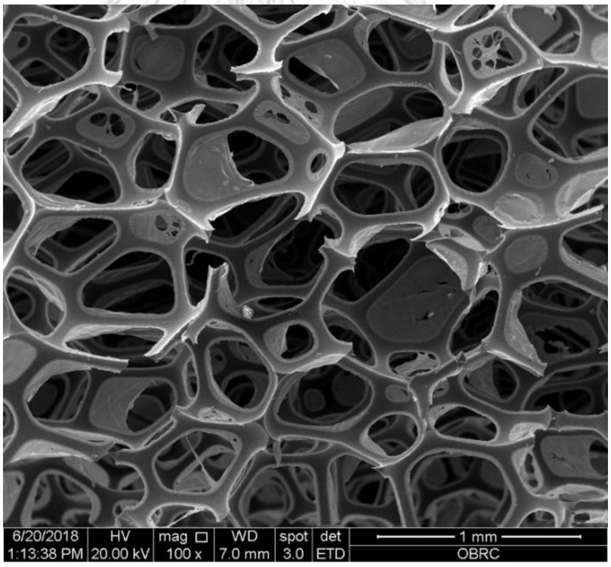

Figure 20 SEM micrographs of test specimen of yellow sponge head.

CHAPTER 5

DISCUSSION

The objective of this study was to determine the dislodgement of sponge head when using different novel Thai-produced sponge brushes. Butler sponge brush was selected as a control group because it is commercial product available in Japan. The novel Thai-produced sponge brush was an experimental group. In this study, the null hypothesis was rejected. Significant differences in the dislodgement of sponge head were shown when using different novel Thai-produced sponge brushes.

The dislodgement of sponge head test was chosen because of safety concern. Incident report from Wales reveals that the dislodgement of sponge head that retained in the mouth can be hazardously choking[12]. Therefore, commercial sponge brush was selected for the test. These product testing has limitation due to the outcome which does not represent population. Nevertheless, it can measure the properties or performance of products. Force/Density value should be calculated to compare the dislodgement of sponge heads. In order to reduce inherent variability, the force should be divided by their density.

Force data was determined following ISO 0126:2012(E)[13]. Because there is no safety and efficiency standards test for spong brush. ISO 20126:2012(E)[13] was adapted. This International Standard specifies the requirements and test method for the physical properties of manual toothbrushes. This test method covers determination of tuft retention, fatigue resistance, chemical challenge, and handle impact strength. In this study tuft retention test (method 5.4.) was chosen. It can be measured and indicated the removal force of sponge head from its handle. The evaluation of manual toothbrush properties are consisted of physical properties and biological hazards. The tuft retention test, one of the physical properties, was chosen from ISO 20126:2012(E) in order to assess the dislodgement of sponge head. However, in the future study, other aspects of ISO 20126:2012(E), that have not been tested in this study yet, should be evaluates as well, including fatigue resistance, chemical challenge and handle impact strength which are all the evalution of toothbrush handle. In addition, the marking and lebelling and the packaging should be also taken into consideration. Specific qualitative and quatitative requirements for freedom from biological hazards are not included in this International Standard. It is recommended that, in assessing possible biological hazards reference be made to ISO 7450 and ISO 10993-1.

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FTIR characterized base polymers from any manufacturers foam. It was firstly confirmed the type of base polymer. ATR-IR spectra of all test specimens corresponded to the same base polymer. Therefore, the density of foam is an appropriate parameter[50]. Although Gas Pycnometer is a device used for measuring the density by using a gas displacement technique to measure the volume, the test specimen is too light to evaluate. Additionally, Pycnometer is a device used for measuring the density by using a water displacement technique to measure the volume, but the test specimen floats on the water. Therefore, micro-CT was chosen in order to determine volume[51]. For the density, it was calculated as mass per unit volume[50].

The dislodgement comparison of sponge heads between different densities of the foam revealed a significant higher strength in Butler sponge brush than the yellow sponge head and the white sponge head, respectively. When comparing the dislodgements of the same foam density, the sponge heads revealed a significant higher resistance to dislodgement of the round shape than the Leelawadee shape in the cross-section. It can be concluded that the higher density foam has more strength than the lower density foam [46-48].

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CHAPTER 6

CONCLUSIONS

Sponge brush is one of the oral hygiene instrument. It is recommended for moisturizing gel application to the oral cavity by softening the hard secretion and swabing to remove crusts from oral mucosa. In Thailand, the sponge brush was just first produced in order to decrease the importations from Japan. From the tested results, we concluded that yellow sponge head in cross-section round shape had the most resistance to dislodgement, compared to four novel Thai-produced sponge brushes. Because of its density that relates to all physical properties. The higher density of the foam results in the higher strength. By the way, fatigue resistance and handle impact test should be conducted for assessing the physical properties of handles. Biological hazards should be the greatest concern to assessing possible biological hazards. For the clinical applications, there should be a further study to evaluate the proper uses and applications in human oral cavity environment.

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APPENDICES

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APPENDIX A

The analytical data of Micro-CT

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Japan–1 SCANCO MEDICAL

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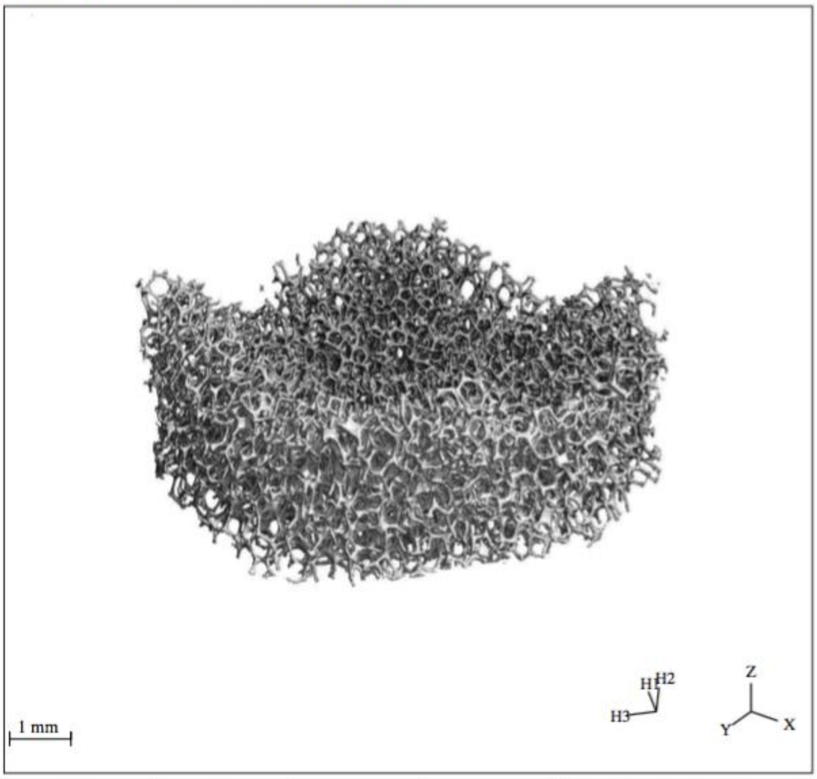

VOI	X	Y	Z	Mean/Density [mg HA/ccm]
Position [p]	128	164	2	of TV (Apparent) -193.2263
Dimension [p]	776	768	418	of BV (Material) ~ -58.398
Element Size [mm]	0.0120	0.0120	0.0120	

Direct (No Model)			TRI (Plate Model)			Anisotropy		
TV	[mm³]	189.5751	TV	[mm³]	187.1150	|H1|	[mm]	0.7109
BV	[mm³]	7.8052	BV	[mm³]	7.4104	|H2|	[mm]	0.7743
BV/TV	[1]	0.0412	BV/TV	[1]	0.0396	|H3|	[mm]	0.7175
Conn. D.	[1/mm³]	25.9976	BS	[mm²]	510.9108	DA	[1]	1.0892
SMI	[1]	2.3276	BS/BV	[1/mm]	68.9450			
Tb.N*	[1/mm]	2.0089	Tb.N	[1/mm]	1.3652	Segmentation: 0.8 / 1 / 16		
Tb.Th*	[mm]	0.0399	Tb.Th	[mm]	0.0290	Operator Meas.: Boonsong		
Tb.Sp*	[mm]	0.5094	Tb.Sp	[mm]	0.7035	Operator Eval.:		

μCT 35
SCANCO MEDICAL

Figure A1 represents 3D Micro-CT reconstructions of test specimens from sponge head with Sakura-shaped in cross-section (test specimen No.1).

Japan–2 SCANCO MEDICAL

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S-No.: 6510 Filename: C0008145

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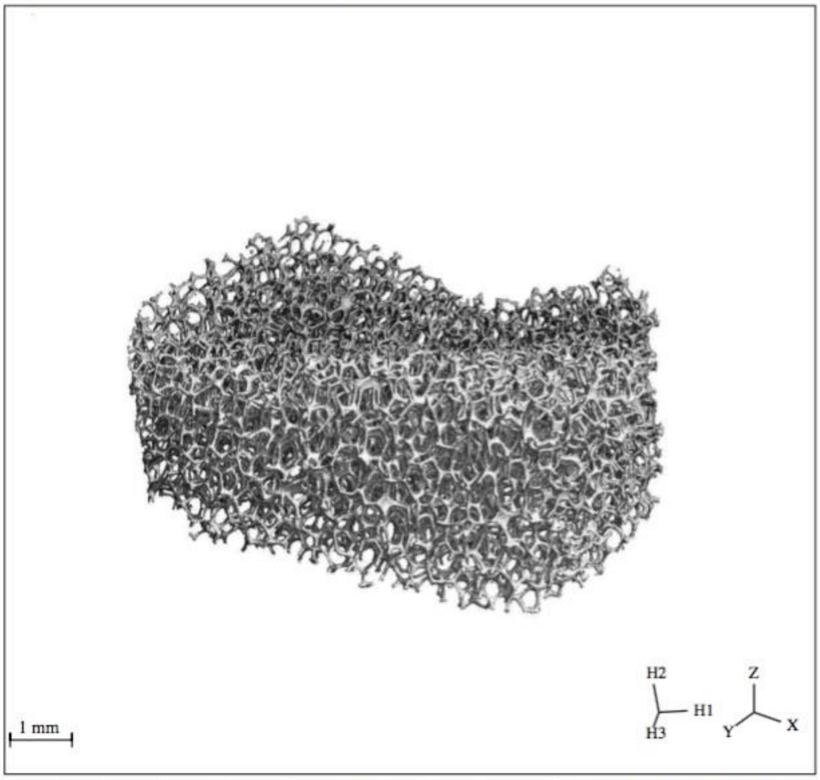

VOI	X	Y	Z	Mean/Density [mg HA/ccm]
Position [p]	110	151	17	of TV (Apparent) -192.5834
Dimension [p]	804	748	375	of BV (Material) ~ -56.286
Element Size [mm]	0.0120	0.0120	0.0120	

Direct (No Model)		TRI (Plate Model)		Anisotropy	
TV [mm³]	199.6633	TV [mm³]	198.0232	|H1| [mm]	0.6993
BV [mm³]	8.2120	BV [mm³]	7.8871	|H2| [mm]	0.7782
BV/TV [1]	0.0411	BV/TV [1]	0.0398	|H3| [mm]	0.7164
Conn. D. [1/mm³]	27.9996	BS [mm²]	543.2919	DA [1]	1.1127
SMI [1]	2.3101	BS/BV [1/mm]	68.8833		
Tb.N* [1/mm]	1.9866	Tb.N [1/mm]	1.3718	Segmentation: 0.8 / 1 / 16	
Tb.Th* [mm]	0.0405	Tb.Th [mm]	0.0290	Operator Meas.: Boonsong	
Tb.Sp* [mm]	0.5151	Tb.Sp [mm]	0.6999	Operator Eval.:	

μCT 35

SCANCO MEDICAL

Figure A2 represents 3D Micro-CT reconstructions of test specimens from sponge head with Sakura-shaped in cross-section (test specimen No.2).

Japan–3 SCANCO MEDICAL

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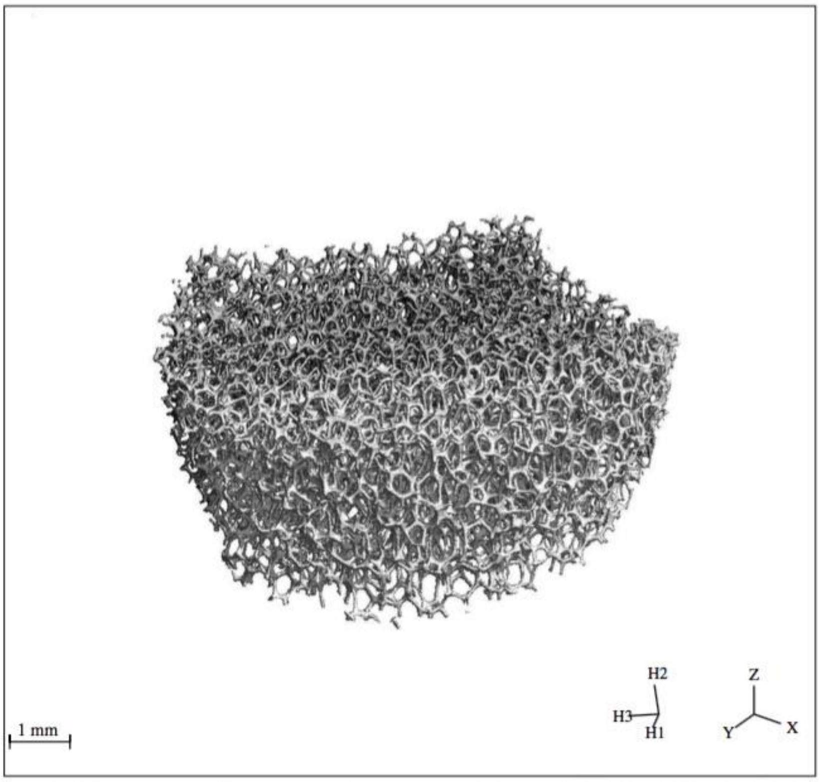
S-No.: 6511 Filename: C0008146
M-No.: 10195 Date: 14–JUN–2018 22:15



VOI	X	Y	Z	Mean/Density [mg HA/ccm]
Position [p]	123	135	11	of TV (Apparent) −192.2160
Dimension [p]	812	820	310	of BV (Material) ~ −55.000
Element Size [mm]	0.0120	0.0120	0.0120	

Direct (No Model)			TRI (Plate Model)			Anisotropy		
TV	[mm³]	200.3068	TV	[mm³]	198.5661	|H1|	[mm]	0.6816
BV	[mm³]	8.6195	BV	[mm³]	8.2906	|H2|	[mm]	0.7511
BV/TV	[1]	0.0430	BV/TV	[1]	0.0418	|H3|	[mm]	0.6838
Conn. D.	[1/mm³]	29.1453	BS	[mm²]	564.6751	DA	[1]	1.1020
SMI	[1]	2.2837	BS/BV	[1/mm]	68.1104			
Tb.N*	[1/mm]	2.0125	Tb.N	[1/mm]	1.4219	Segmentation: 0.8 / 1 / 16		
Tb.Th*	[mm]	0.0406	Tb.Th	[mm]	0.0294	Operator Meas.: Boonsong		
Tb.Sp*	[mm]	0.5101	Tb.Sp	[mm]	0.6739	Operator Eval.:		

μCT 35
SCANCO MEDICAL

Figure A3 represents 3D Micro-CT reconstructions of test specimens from sponge head with Sakura-shaped in cross-section (test specimen No.3).

white–1 SCANCO MEDICAL

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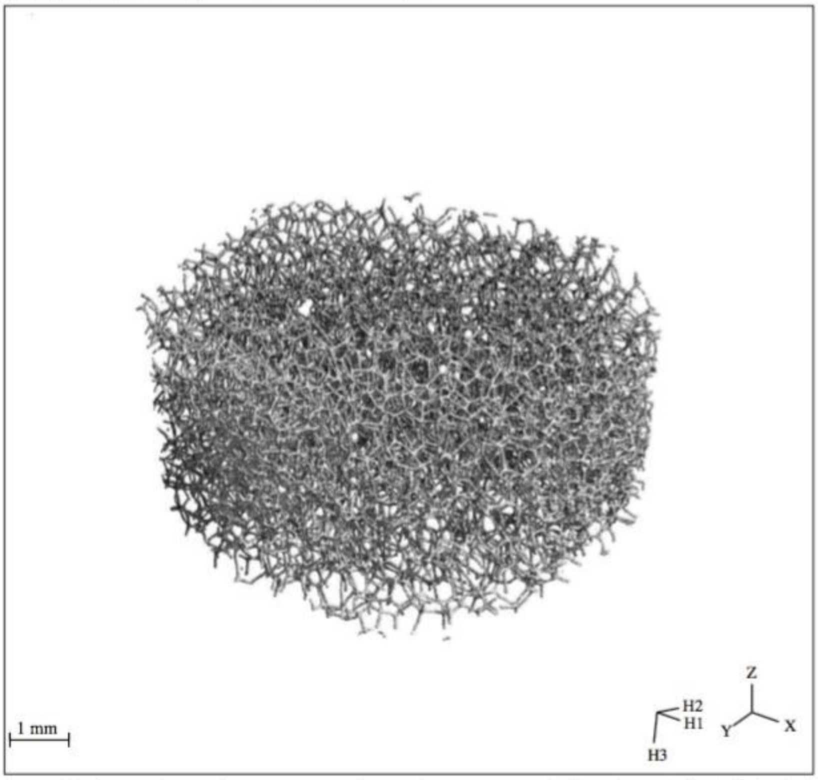
S-No.: 6530 Filename: C0008149
M-No.: 10198 Date: 15–JUN–2018 02:11



VOI	X	Y	Z	Mean/Density [mg HA/ccm]
Position [p]	170	95	2	of TV (Apparent) −195.0632
Dimension [p]	800	816	422	of BV (Material) ~ −20.834
Element Size [mm]	0.0120	0.0120	0.0120	

Direct (No Model)		TRI (Plate Model)		Anisotropy	
TV [mm³]	308.9670	TV [mm³]	306.8102	|H1| [mm]	1.6026
BV [mm³]	4.2919	BV [mm³]	3.5357	|H2| [mm]	1.6752
BV/TV [1]	0.0139	BV/TV [1]	0.0115	|H3| [mm]	1.6376
Conn. D. [1/mm³]	15.4450	BS [mm²]	374.8275	DA [1]	1.0453
SMI [1]	2.8534	BS/BV [1/mm]	106.0116		
Tb.N* [1/mm]	1.5238	Tb.N [1/mm]	0.6108	Segmentation: 0.8 / 1 / 16	
Tb.Th* [mm]	0.0285	Tb.Th [mm]	0.0189	Operator Meas.: Boonsong	
Tb.Sp* [mm]	0.6592	Tb.Sp [mm]	1.6182	Operator Eval.:	

µCT 35
SCANCO MEDICAL

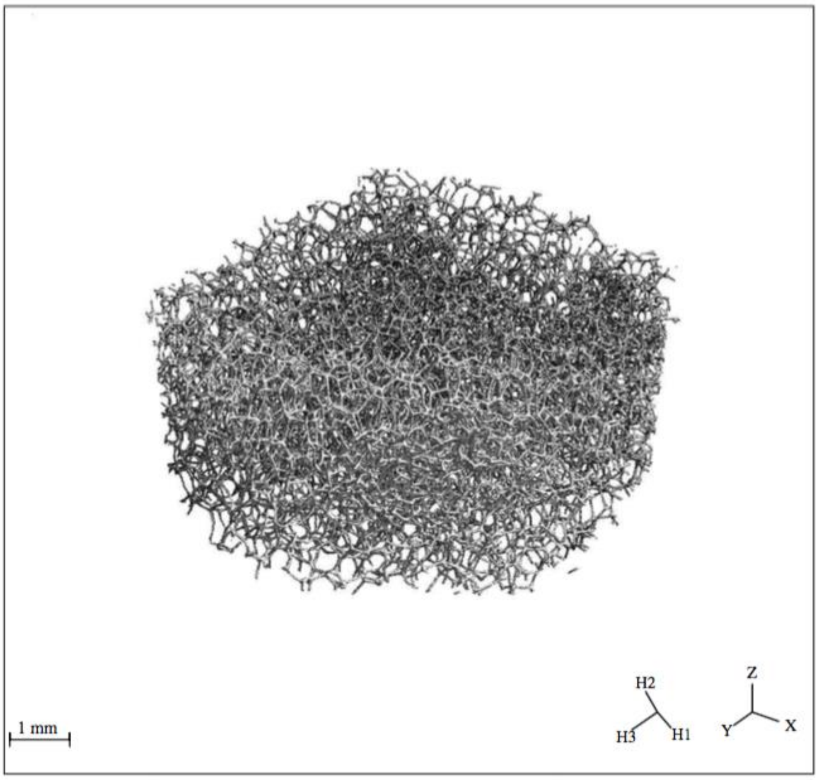
Figure A4 represents 3D Micro-CT reconstructions of test specimens from white sponge head (test specimen No.1).

white–2 **SCANCO MEDICAL**

Ó à. p r ú

S-No.: 6531 Filename: C0008150

M-No.: 10199 Date: 15–JUN–2018 03:36



VOI	X	Y	Z	Mean/Density [mg HA/ccm]
Position [p]	133	145	2	of TV (Apparent) −195.5224
Dimension [p]	788	788	438	of BV (Material) − −18.262
Element Size [mm]	0.0120	0.0120	0.0120	

Direct (No Model)		TRI (Plate Model)		Anisotropy	
TV [mm³]	299.8324	TV [mm³]	297.7520	|H1| [mm]	1.5726
BV [mm³]	4.2201	BV [mm³]	3.4821	|H2| [mm]	1.6574
BV/TV [1]	0.0141	BV/TV [1]	0.0117	|H3| [mm]	1.5997
Conn. D. [1/mm³]	15.5187	BS [mm²]	370.2865	DA [1]	1.0539
SMI [1]	2.8553	BS/BV [1/mm]	106.3392		
Tb.N* [1/mm]	1.5721	Tb.N [1/mm]	0.6218	Segmentation:	0.8 / 1 / 16
Tb.Th* [mm]	0.0284	Tb.Th [mm]	0.0188	Operator Meas.:	Boonsong
Tb.Sp* [mm]	0.6384	Tb.Sp [mm]	1.5894	Operator Eval.:	

µCT 35

SCANCO MEDICAL

Figure A5 represents 3D Micro-CT reconstructions of test specimens from white sponge head (test specimen No.2).

white–3 SCANCO MEDICAL

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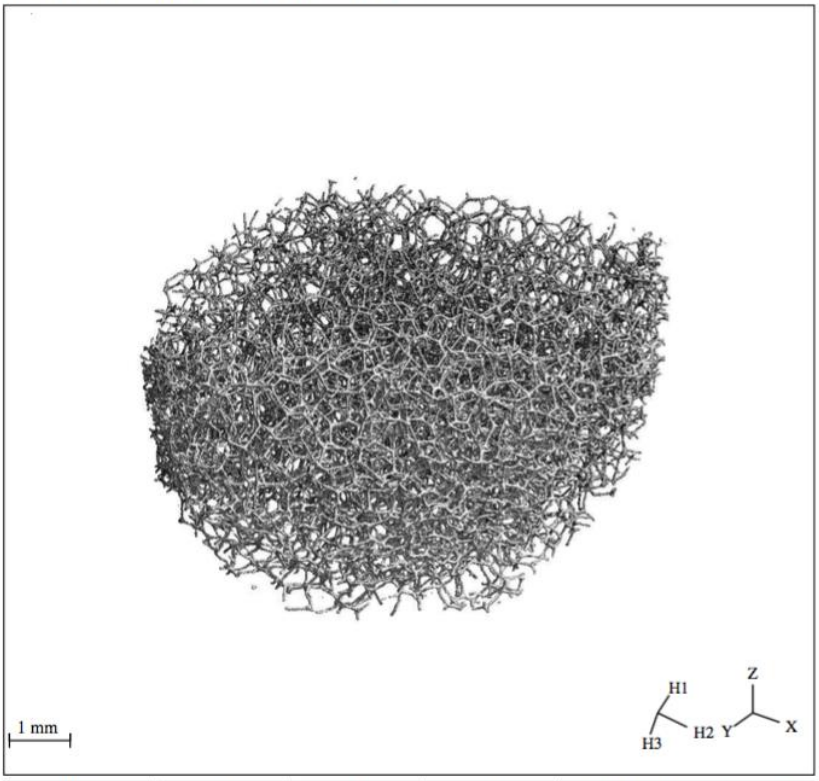
S-No.: 6532 Filename: C0008151

M-No.: 10200 Date: 15–JUN–2018 05:01



VOI	X	Y	Z	Mean/Density [mg HA/ccm]
Position [p]	129	153	33	of TV (Apparent) -194.9713
Dimension [p]	776	796	405	of BV (Material) ~ -16.517
Element Size [mm]	0.0120	0.0120	0.0120	

Direct (No Model)		TRI (Plate Model)		Anisotropy	
TV [mm³]	306.1318	TV [mm³]	304.4272	|H1| [mm]	1.5377
BV [mm³]	4.3823	BV [mm³]	3.6514	|H2| [mm]	1.6707
BV/TV [1]	0.0143	BV/TV [1]	0.0120	|H3| [mm]	1.5968
Conn. D. [1/mm³]	15.3071	BS [mm²]	380.8493	DA [1]	1.0865
SMI [1]	2.8409	BS/BV [1/mm]	104.3034		
Tb.N* [1/mm]	1.5769	Tb.N [1/mm]	0.6255	Segmentation: 0.8 / 1 / 16	
Tb.Th* [mm]	0.0287	Tb.Th [mm]	0.0192	Operator Meas.: Boonsong	
Tb.Sp* [mm]	0.6370	Tb.Sp [mm]	1.5795	Operator Eval.:	

µCT 35

SCANCO MEDICAL

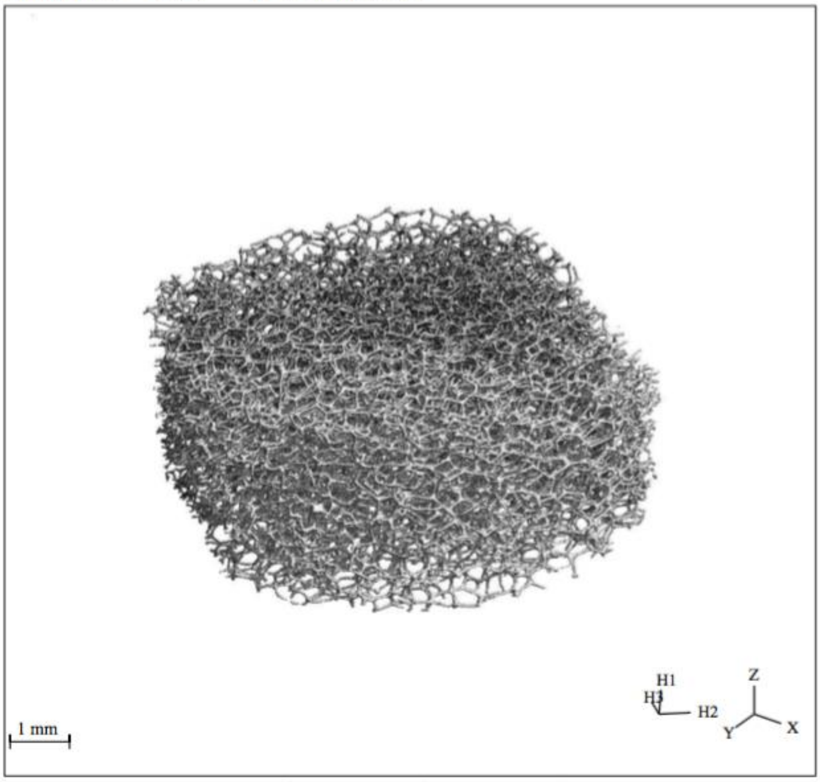
Figure A6 represents 3D Micro-CT reconstructions of test specimens from white sponge head (test specimen No.3).

yellow–1 SCANCO MEDICAL

v à. p r ú

S-No.: 6513 Filename: C0008129

M-No.: 10169 Date: 14–JUN–2018 09:55



VOI	X	Y	Z	Mean/Density [mg HA/ccm]
Position [p]	161	87	31	of TV (Apparent) −193.9610
Dimension [p]	828	820	331	of BV (Material) ~ −30.110
Element Size [mm]	0.0120	0.0120	0.0120	

Direct (No Model)		TRI (Plate Model)		Anisotropy	
TV [mm³]	246.3151	TV [mm³]	244.5753	|H1| [mm]	0.8919
BV [mm³]	6.2008	BV [mm³]	5.3905	|H2| [mm]	1.0881
BV/TV [1]	0.0252	BV/TV [1]	0.0220	|H3| [mm]	0.9364
Conn. D. [1/mm³]	33.2298	BS [mm²]	508.0486	DA [1]	1.2200
SMI [1]	2.7472	BS/BV [1/mm]	94.2493		
Tb.N* [1/mm]	1.9541	Tb.N [1/mm]	1.0386	Segmentation: 0.8 / 1 / 16	
Tb.Th* [mm]	0.0309	Tb.Th [mm]	0.0212	Operator Meas.: Boonsong	
Tb.Sp* [mm]	0.5170	Tb.Sp [mm]	0.9416	Operator Eval.:	

μCT 35

SCANCO MEDICAL

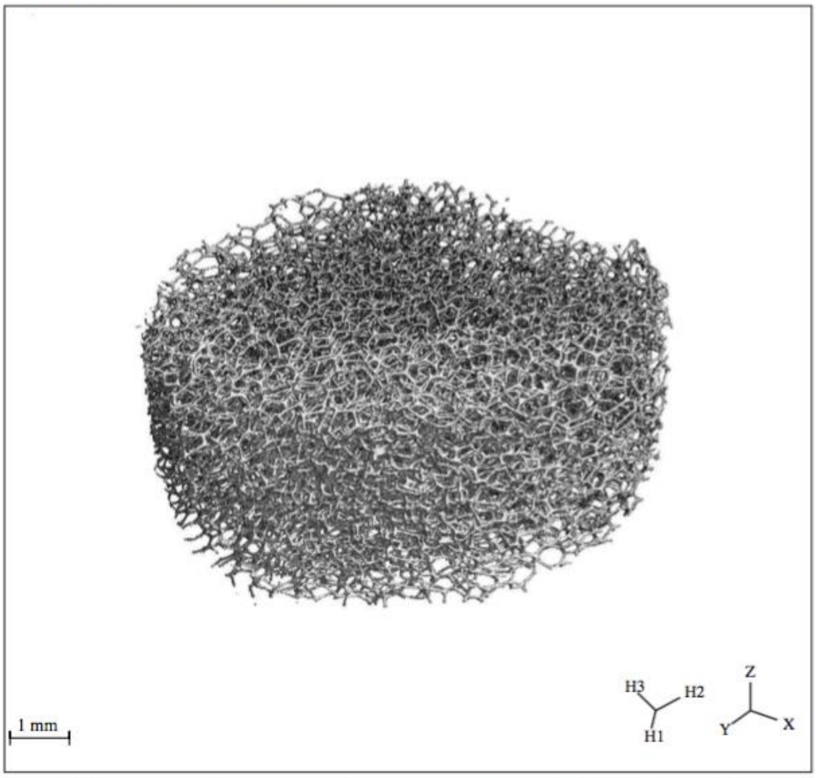
Figure A7 represents 3D Micro-CT reconstructions of test specimens from yellow sponge head (test specimen No.1).

yellow–2 SCANCO MEDICAL

° à. p r ú

S-No.: 6528 Filename: C0008147

M-No.: 10196 Date: 14–JUN–2018 23:21



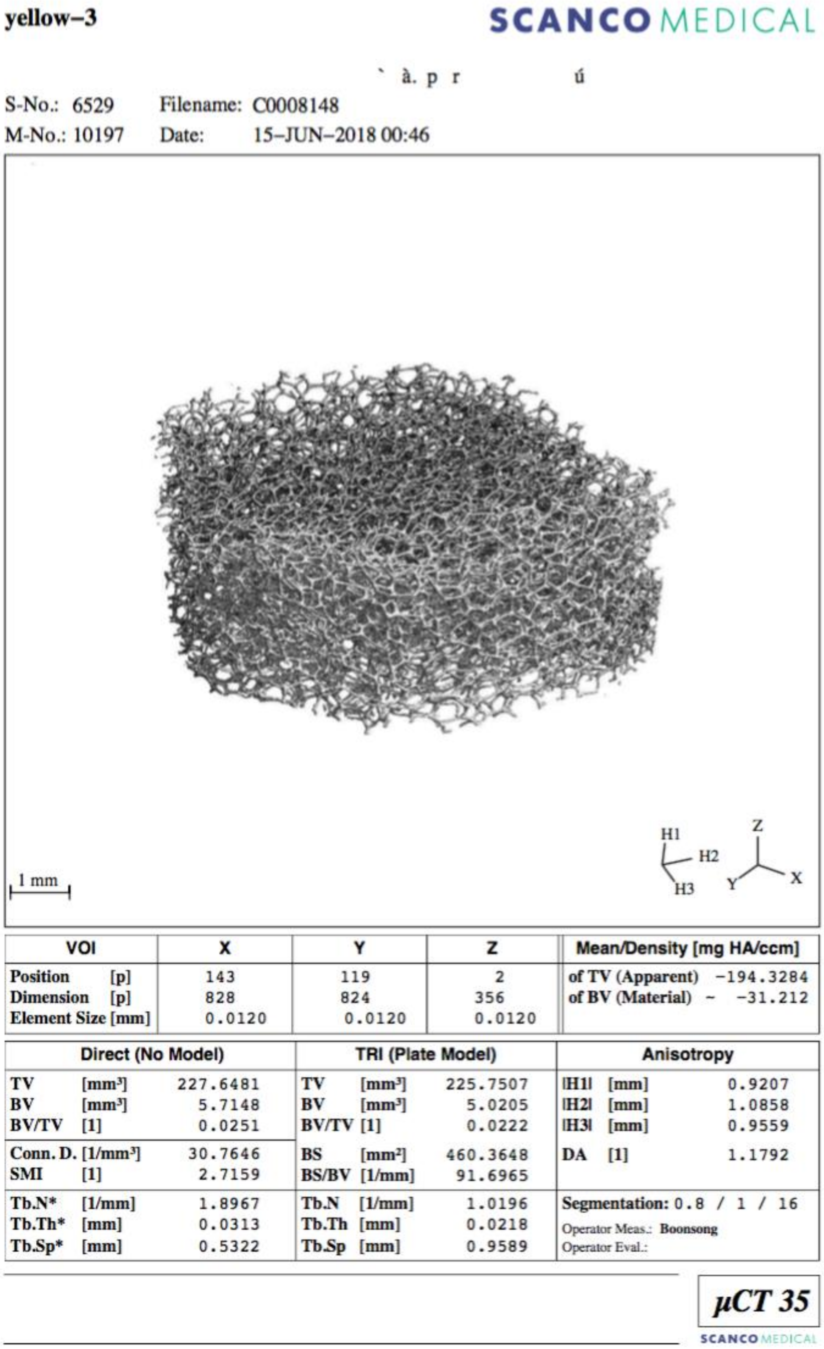
VOI	X	Y	Z	Mean/Density [mg HA/ccm]
Position [p]	131	128	12	of TV (Apparent) -194.2366
Dimension [p]	800	812	396	of BV (Material) ~ -27.722
Element Size [mm]	0.0120	0.0120	0.0120	

Direct (No Model)		TRI (Plate Model)		Anisotropy	
TV [mm³]	290.3680	TV [mm³]	288.2817	|H1| [mm]	0.8519
BV [mm³]	7.7689	BV [mm³]	6.8575	|H2| [mm]	1.0459
BV/TV [1]	0.0268	BV/TV [1]	0.0238	|H3| [mm]	0.9034
Conn. D. [1/mm³]	31.9009	BS [mm²]	623.7156	DA [1]	1.2278
SMI [1]	2.7081	BS/BV [1/mm]	90.9541		
Tb.N* [1/mm]	2.0099	Tb.N [1/mm]	1.0818	Segmentation: 0.8 / 1 / 16	
Tb.Th* [mm]	0.0315	Tb.Th [mm]	0.0220	Operator Meas.: Boonsong	
Tb.Sp* [mm]	0.5023	Tb.Sp [mm]	0.9024	Operator Eval.:	

μCT 35

SCANCO MEDICAL

Figure A8 represents 3D Micro-CT reconstructions of test specimens from yellow sponge head (test specimen No.2).



yellow–3 SCANCO MEDICAL

S-No.: 6529 Filename: C0008148

M-No.: 10197 Date: 15–JUN–2018 00:46

VOI	X	Y	Z	Mean/Density [mg HA/ccm]
Position [p]	143	119	2	of TV (Apparent) -194.3284
Dimension [p]	828	824	356	of BV (Material) ~ -31.212
Element Size [mm]	0.0120	0.0120	0.0120	

Direct (No Model)		TRI (Plate Model)		Anisotropy	
TV [mm³]	227.6481	TV [mm³]	225.7507	|H1| [mm]	0.9207
BV [mm³]	5.7148	BV [mm³]	5.0205	|H2| [mm]	1.0858
BV/TV [1]	0.0251	BV/TV [1]	0.0222	|H3| [mm]	0.9559
Conn. D. [1/mm³]	30.7646	BS [mm²]	460.3648	DA [1]	1.1792
SMI [1]	2.7159	BS/BV [1/mm]	91.6965		
Tb.N* [1/mm]	1.8967	Tb.N [1/mm]	1.0196	Segmentation: 0.8 / 1 / 16	
Tb.Th* [mm]	0.0313	Tb.Th [mm]	0.0218	Operator Meas.: Boonsong	
Tb.Sp* [mm]	0.5322	Tb.Sp [mm]	0.9589	Operator Eval.:	

µCT 35 SCANCO MEDICAL

Figure A9 represents 3D Micro-CT reconstructions of test specimens from yellow sponge head (test specimen No. 3).

APPENDIX B

The dislodgement data of sponge head test

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University

Table B1 Maximum forces that completely separated sponge head with Sakura-shaped in cross-section from its handle.

Sample number	Force (N)	Density (kg/m^3)
1	12.6725	48.53
2	11.7050	48.53
3	13.3475	48.53
4	11.6250	48.53
5	14.3800	48.53
6	12.1150	48.53
7	14.0225	48.53
8	14.7400	48.53
9	12.0500	48.53
10	13.5600	48.53
11	10.8975	48.53
12	10.6150	48.53
13	12.1225	48.53
14	11.6425	48.53
15	11.2975	48.53
16	15.8325	48.53
17	13.9025	48.53
18	11.2125	48.53
19	11.1375	48.53
20	13.6425	48.53

จุฬาลงกรณ์มหาวิทยาลัย
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Sample number	Force (N)	Density (kg/m^3)
21	14.5600	48.53
22	13.4075	48.53
23	14.8350	48.53
24	12.0325	48.53
25	12.3450	48.53
26	11.9700	48.53
27	14.0925	48.53
28	13.7650	48.53
29	14.0875	48.53
30	11.7950	48.53

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University

Table B2 Maximum forces that completely separated white sponge head with round shaped in cross-section from its handle.

Sample number	Force (N)	Density (kg/m^3)
1	11.0250	16.17
2	11.7475	16.17
3	11.7475	16.17
4	11.7475	16.17
5	11.0350	16.17
6	12.1050	16.17
7	11.2275	16.17
8	10.6800	16.17
9	10.4775	16.17
10	10.9650	16.17
11	12.4575	16.17
12	10.3800	16.17
13	12.2975	16.17
14	12.0300	16.17
15	10.7725	16.17
16	11.4575	16.17
17	11.2075	16.17
18	10.9750	16.17
19	11.3425	16.17
20	12.3975	16.17

จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

Sample number	Force (N)	Density (kg/m^3)
21	11.2775	16.17
22	11.1450	16.17
23	10.9250	16.17
24	11.1525	16.17
25	11.1575	16.17
26	12.4100	16.17
27	10.8950	16.17
28	10.5525	16.17
29	11.5550	16.17
30	10.5275	16.17

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University

Table B3 Maximum forces that completely separated white sponge head with Leelawadee shaped in cross-section from its handle.

Sample number	Force (N)	Density (kg/m^3)
1	9.2425	16.17
2	9.2825	16.17
3	11.0125	16.17
4	10.9100	16.17
5	10.0075	16.17
6	10.1050	16.17
7	9.7425	16.17
8	9.6700	16.17
9	9.8025	16.17
10	10.5475	16.17
11	9.4425	16.17
12	10.9125	16.17
13	10.0200	16.17
14	10.9000	16.17
15	10.3150	16.17
16	10.0950	16.17
17	10.6375	16.17
18	10.1650	16.17
19	11.0500	16.17
20	9.7400	16.17

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University

Sample number	Force (N)	Density (kg/m^3)
21	10.5775	16.17
22	9.7450	16.17
23	10.6225	16.17
24	10.2425	16.17
25	10.9850	16.17
26	10.9150	16.17
27	10.4825	16.17
28	10.3800	16.17
29	10.1350	16.17
30	11.0125	16.17

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University

Table B4 Maximum forces that completely separated yellow sponge head with round shaped in cross-section from its handle.

Sample number	Force (N)	Density (kg/m^3)
1	16.9650	28.56
2	17.2100	28.56
3	16.7500	28.56
4	17.6925	28.56
5	14.9775	28.56
6	15.4625	28.56
7	17.2850	28.56
8	16.4500	28.56
9	14.7325	28.56
10	17.4175	28.56
11	15.8125	28.56
12	17.4025	28.56
13	16.4550	28.56
14	16.5125	28.56
15	16.8900	28.56
16	14.2000	28.56
17	17.2525	28.56
18	16.7125	28.56
19	16.4275	28.56
20	16.6600	28.56

จุฬาลงกรณ์มหาวิทยาลัย
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Sample number	Force (N)	Density (kg/m^3)
21	15.9525	28.56
22	15.6525	28.56
23	17.5875	28.56
24	14.4075	28.56
25	15.3925	28.56
26	14.3875	28.56
27	16.7675	28.56
28	17.5800	28.56
29	15.8800	28.56
30	16.1700	28.56

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University

Table B5 Maximum forces that completely separated yellow sponge head with Leelawadee shaped in cross-section from its handle.

Sample number	Force (N)	Density (kg/m^3)
1	14.7150	28.56
2	15.8825	28.56
3	14.0875	28.56
4	14.5875	28.56
5	14.8600	28.56
6	14.7775	28.56
7	14.1050	28.56
8	14.4575	28.56
9	14.4175	28.56
10	15.0575	28.56
11	15.2025	28.56
12	15.3950	28.56
13	15.1900	28.56
14	13.8550	28.56
15	14.8925	28.56
16	14.1275	28.56
17	16.2075	28.56
18	14.0675	28.56
19	14.9250	28.56
20	16.0100	28.56

จุฬาลงกรณ์มหาวิทยาลัย
Chulalongkorn University

Sample number	Force (N)	Density (kg/m^3)
21	14.6850	28.56
22	14.2425	28.56
23	16.1800	28.56
24	15.5350	28.56
25	14.0100	28.56
26	15.8825	28.56
27	15.1300	28.56
28	16.0625	28.56
29	15.0975	28.56
30	14.3350	28.56

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