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The development of wax cubes hardness for chewing ability evaluation

Ms. Sirilada Liangbunyaphan

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By	Miss Sirilada Liangbunyaphan
Field of Study	Prosthodontics
Thesis Advisor	Assistant Professor Orapin Kaewplung, Ph.D.
Thesis Co-advisor	Associate Professor Amorn Petsom, Ph.D.

Accepted by the Faculty of Dentistry, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

……………………………………………Dean of the Faculty of Dentistry
(Associate Professor Wacharaporn Tasachan)

THESIS COMMITTEE

……………………………………………….. Chairman
(Associate Professor Mansuang Arksornnukit, Ph.D.)

……………………………………………….. Thesis Advisor
(Assistant Professor Orapin Kaewplung, Ph.D.)

……………………………………………….. Thesis Co-advisor
(Associate Professor Amorn Petsom, Ph.D.)

……………………………………………….. Examiner
(Wacharasak Tumrasvin, Ph.D.)

……………………………………………….. External Examiner
(Associate Professor Rumpai Rochanakit)

สิริลดา เลี้ยงบุญญพันธ์ : การพัฒนาความแข็งของชิ้นขี้ผึ้งเพื่อใช้ประเมินประสิทธิภาพในการบดเคี้ยว. (The development of wax cubes hardness for chewing ability evaluation) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ.ทญ.ดร. อรพินท์ แก้วปลั่ง, อ.ที่ปรึกษาวิทยานิพนธ์ร่วม: รศ.ดร. อมร เพชรสม, 55 หน้า.

การศึกษานี้มีวัตถุประสงค์เพื่อพัฒนาความแข็งของชิ้นขี้ผึ้งเพื่อใช้ในการประเมินความสามารถในการบดเคี้ยวในผู้ป่วยไร้ฟันที่ใส่ฟันเทียมทั้งปากโดยกระบวนการที่สามารถทำได้ในประเทศไทย และหาความแข็งที่เหมาะสมที่ผู้ป่วยจะมีความสามารถในการบดเคี้ยวใกล้เคียงกับผู้ที่มีฟันธรรมชาติ ชิ้นขี้ผึ้ง 3 ชนิด ได้แก่ ชนิด แข็ง ชนิดแรกเริ่ม และชนิดนิ่ม ถูกผลิตขึ้นโดยอัตราส่วนที่แตกต่างกันระหว่างไขผึ้งและขี้ผึ้งไมโครคริสตอล ความแข็งของชิ้นขี้ผึ้งทั้ง 3 ชนิด และตัวอย่างอาหารทั่วไป 16 ชนิด ถูกทดสอบด้วยเครื่องทดสอบเอนกประสงค์ ผู้เข้าร่วมวิจัยประกอบด้วยกลุ่มฟันธรรมชาติ จำนวน 20 คน (อายุเฉลี่ย 27.85±1.42 ปี) กลุ่มฟันเทียมทั้งปาก จำนวน 20 คน (อายุเฉลี่ย 70.55±9.14 ปี)และกลุ่มฟันเทียมล่างทับรากเทียม จำนวน 20 คน (อายุเฉลี่ย67.70±6.68 ปี) ให้ผู้เข้าร่วม วิจัยเคี้ยวชิ้นขี้ผึ้ง 3 ชนิด ชนิดละ 3 ชิ้น ครั้งละชิ้น ชิ้นละ 10 ครั้ง ในตำแหน่งที่ถนัด นำชิ้นขี้ผึ้งที่ผ่านการเคี้ยวแล้วไปถ่ายภาพและวิเคราะห์ความสามารถในการบดเคี้ยวด้วยโปรแกรมอิมเมจเจที่คำนวนร้อยละของสีที่ผสมกันได้ดี จากสถิติวิเคราะห์ พบว่า มีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติของร้อยละของความสามารถในการบดเคี้ยว (P < .05) ระหว่างกลุ่มตัวอย่าง 2 กลุ่ม เฉพาะในการเคี้ยวชิ้นขี้ผึ้งชนิดแรกเริ่มและชนิดนิ่มเท่านั้น กลุ่มฟันเทียมทั้งปากมีความสามารถในการบดเคี้ยวขี้ผึ้งชนิดแรกเริ่มและชนิดนิ่มลดลงประมาณร้อยละ 35 เมื่อเปรียบเทียบกับกลุ่มฟันธรรมชาติกลุ่มฟันเทียมล่างทับรากเทียมมีความสามารถในการบดเคี้ยวสูงกว่ากลุ่มฟันเทียมทั้งปาก จากการศึกษา พบว่า ความแข็งของชิ้นขี้ผึ้งที่เหมาะสมในการประเมินความสามารถในการบดเคี้ยวในผู้ป่วยไร้ฟันที่ใส่ฟันเทียมทั้งปาก คือ ชิ้นขี้ผึ้งชนิดแรกเริ่มและชนิดนิ่ม และชิ้นขี้ผึ้งทั้งสองอยู่ในช่วงความแข็งของตัวอย่างอาหารที่เลือกมาทดสอบ การศึกษานี้แนะนำว่า ชิ้นขี้ผึ้งเป็นอีกทางเลือกหนึ่งที่สามารถนำมาใช้ในการคัดกรองความสามารถในการบดเคี้ยวร่วมกับเครื่องมืออื่นๆในการประเมินสภาวะโภชนาการของผู้สูงอายุได้

ภาควิชา ทันตกรรมประดิษฐ์	ลายมือชื่อนิสิต
สาขาวิชา ทันตกรรมประดิษฐ์	ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก
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SIRILADA LIANGBUNYAPHAN: THE DEVELOPMENT OF WAX CUBES HARDNESS FOR CHEWING ABILITY EVALUATION. ADVISOR : ASST. PROF. ORAPIN KAEWPLUNG, CO-ADVISOR : ASSOC. PROF. AMORN PETSOM, 55 pp.

The purposes of this study were to develop wax cube hardness for chewing ability evaluation in total edentulous patient with complete denture by the practical process in Thailand and to find the suitable hardness that those patients have chewing ability close to normal dentitions. Three formulations of wax cube; hard, original and soft, were developed by different mixture ratio of bees wax and microcrystalline wax. Hardness of three types of wax cube and sixteen common foods were obtained from Universal Testing Machine. 20 normal dentition (mean age 27.85±1.42 years), 20 complete denture wearer subjects (mean age 70.55±9.14 years) and 20 implant-retained lower complete denture (mean age 67.70±6.68 years) were selected. Each subject was assigned to chew three pieces of each hardness of wax cube, one cube by another for 10 chewing strokes under habitually chewing patterns. The chewed wax was captured and analyzed by the Image J program ,which calculated the percentage of well mixed color areas. Statistically analysis revealed a significant difference (P < .05) in percentage of chewing ability between two groups with only original and soft wax cubes. Complete Denture group had reduced about 35 percent for chewing original and soft wax cubes when compare to normal dentition group. Implant-retained lower complete denture group showed the higher percentage of chewing ability than complete denture group. From the study, it can be concluded that the suitable hardness chewing ability evaluation in total edentulous patient with complete denture are the original and soft wax cubes and these are in the same range as common food selected. Our results suggested that the wax cube is the one option for screening chewing ability accompanied by some nutritional assessment tools to evaluate nutritional status in the elderly patients

Department : Prosthodontics	Student's Signature ....
Field of Study : Prosthodontics	Advisor's Signature ....
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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
BMI	Body Mass Index
Fig	figure
K	Kelvin
l	liter
min	minute
mm	millimeter
MNA	Mini Nutritional Assessment
N	Newton
SD	standard deviation
^{o}C	degree Celcius

CHAPTER I

INTRODUCTION

The quality of life is influenced by many factors and ones of them are the loss of teeth, decrease of food ingestion and poor diet when referring to the edentulous elderly population (1). A number of studies have demonstrated the relation between edentulousness and diet (2). Totally edentulous adults who wear complete dentures will result in difficulty chewing food, then change in dietary habits by selection soft, easy-to-chew, low fiber diet which contains high amounts of carbohydrates and fats and these lead to malnutrition condition (3, 4). Consequently, some concern has been expressed that edentulous patients at a higher risk of developing serious cardiovascular disease and bowel cancer (5).

Selection of soft food in complete denture patients are because of the maximal bite force in the denture wearers was 5-6 times lower than in the dentate subjects (6), uncomfortable feeling while chewing some hard foods (7), or the reduction of vertical mandibular displacement and velocity in the elderly (8).

In prosthetic treatment, restoration of natural teeth or replacement of missing teeth is performed to recover masticatory function. Varieties of chewing tests have been developed in order to evaluate masticatory function. The evaluation of masticatory function can be divided into two methods. One is subjective evaluation by using questionaires or patient interviews (2, 9, 10). The other is objective evaluation which, being quantitative, allows for comparison with other studies (11, 12) such as sieving method (12-17), chewing gum method (18-20) or wax cube analysis method (21-23). For example, a two-colored (red/white) wax cube has been developed to estimate food mixing ability by Prapatrungsri, et al (23). This method can be utilized clinically to evaluate chewing ability after dental treatment both in normal dentition (23) and removable dental prostheses group (24). The chewing ability determined in those study reflected the ability to blend white and red wax cubes together while chewing in controlled chewing strokes and used the color value of well mixed wax, so called "standard color value", to identify the best chewing ability (23). The chewed wax having more standard color value would present better chewing ability of those subjects (23).

However, the development of the wax cube into different levels of hardness, which can simulate a range of some common foods, will be used to determine the chewing ability of the elderly patients and suggest the suitable foods for their individual ability.

Research Question

Can the developed wax cube evaluate the chewing ability of totally edentulous or elderly patients?

Objectives

1. To develop wax cube hardness for chewing ability evaluation in totally edentulous patients with complete denture and implant-retained complete denture
2. To find the suitable hardness for totally edentulous patients to modified with common foods

Hypothesis

Null hypothesis: The hardness of developed wax cube had no effect on chewing ability evaluation in totally edentulous patients.

Alternative hypothesis: The hardness of developed wax cube had effect on chewing ability evaluation in totally edentulous patients.

Expected outcomes

1. The developed wax cube can use for chewing ability evaluation in both normal dentition and edentulous patients.
2. To advice the total edentulous or elderly patients choose some suitable foods as they can chew when comparing their hardness with the wax cube to meet the nutritional values as recommended for daily intake.
3. Reduction of imported materials budget.
4. The results may be the basis for further study.

CHAPTER II

LITERATURE REVIEW

1. Causes of malnutrition in elderly

The numbers of factors including socioeconomic factors, physiological changes, functional disability, and underlying disease contributes to malnutrition in elderly.

Socioeconomic factors and other problems such as poverty, depression, problems with food preparation and eating, lack of supervision and assistance at mealtimes, psychological problems, and underlying diseases have a greater impact on nutritional status than the aging process or age itself (25). Poverty is also a major contributor to malnutrition. Elderly people may have reduced economic status as a result of retirement, inflation, death of their spouses, and increasing health care costs (26). Furthermore, a social aspect to eating and loneliness also being a major contributing factor to malnutrition. Depression, anxiety, and loneliness can undermine the desire to prepare and eat food and have been associated with anorexia, weight loss, and increased morbidity and mortality in older people (27).

Declines in physical and cognitive status often increase with age. The complexity of problems such as declines in gastric acidity, impairment in the function of the intestinal track and kidney, decreasing in immune responsiveness, and cognitive function impairment also affect both of digestion and absorption of foods.

Changes in neuromuscular activity such as decreased bite force and jaw muscle activity maybe compensated by changes in chewing behavior to lengthen of the duration of chewing (28). Jaw muscle activity is also significantly depressed by age (28).

These affect foods such as meat that are hard to chew (29). Bite forces appear to be more slowly and loosely adapted to food texture in the elderly than in the younger people (28). A reduction of vertical mandibular movement and velocity has been observed in elderly individuals, probably associated with muscular impairment (8). Also, the conjunction of lower shear and compression bite forces associated with a slower tooth penetration into the food consequently food breakdown may lead to some chewing problems.

Functional disabilities such as arthritis, stroke, or vision or hearing impairment can affect nutritional status indirectly. The older person may have difficulty to travel to and from grocery stores, carrying groceries, reaching food on shelves, opening cans and packages, and preparing meals in general. Inability to handle eating instruments, see food clearly, or hear other conversation may lead to social isolation, poor eating habits, and subsequent malnutrition (27).

The condition of the oral cavity can also affect nutrition. Tooth loss, dentures and decrease of saliva can be affect the ability to eat and compromise the nutrient intake of elderly people (25). Xerostomia (dry mouth) is a very common side effect of medication, such as antidepressants, antihypertensives, antipsychotics, which are more commonly consumed by the elderly (30). Patients with dry mouth are commonly complaint about taste and chewing impairments. Also, dry mouth creates further impairment for denture wearers as it decreases the ability to wear dentures (28). Moreover, loss of apatite, so called "anorexia", is common in elderly people because of age-related early satiety (31), changes in taste and sensory perceptions, and use of medications that suppress the apatite and decrease their taste sensation (28).

2. Role of dentist to the nutrition and overall health

Reduced food intake and decrease in absorption capacity in elderly people may lead to micronutrients deficiencies, the oral consequences of which are summarized in Table I.

Calcium and vitamin D are important to minimize bone loss and subsequent osteoporosis. Osteoporosis increases the risk of experiencing bone fracture, which has serious consequences with regard to mobility and quality of life. Elderly people are susceptible to vitamin D deficiency owing to age-related renal impairment, reduced exposure to sunlight and reduced efficiency of vitamin D synthesis through the skin (25).

Elderly people often experience reduced efficiency of iron absorption. Health care professionals should encourage elderly people to consume foods containing iron and vitamin C together, because vitamin C promotes iron absorption. An adequate vitamin B status, in particular folate and vitamin B_{12}, is important in preventing dementia (32). Vitamin B_{12} absorption may be compromised owing to gastrointestinal conditions and some medications (32).

A patient's immune response may deteriorate with age. Protein energy malnutrition and deficiencies of zinc, selenium, folate and vitamin A, C and E all influence the body's immune response. Also, adequate intakes of vitamin C and zinc, apart from their roles in immune function, are important for wound healing (25).

Diagnosis of nutritional deficiencies in elderly people is difficult and often not done until clinical signs of advanced nutritional deficiency are present. Early signs of micronutrient deficiencies are often seen initially in the mouth, and therefore, the dentist has an important role in early diagnosis of such deficiencies (25).

Table I Micronutrient deficiencies relevant to elderly people (25)

Nutrient	Signs of deficiency and relevance of nutrient to oral health
Calcium	Deficiency contributes to osteoporosis and may contribute to alveolar bone loss
Iron	Glossitis, angular cheilitis, mucosal thinning, ulcerations
Zinc	Important in immune function and wound healing; deficiency may exacerbate oral wound healing
Vitamin C	Important in immune function and wound healing; deficiency may exacerbate oral infections; oral sign of deficiency include red spongy gingiva that bleed on probing (in cases of severe deficiency, extensive destruction of periodontal tissues may occur)
Vitamin D	Deficiency contributes to osteoporosis
Folic Acid	Oral signs of deficiency include painful glossitis (tongue is swollen and tender to the touch), atrophy of tongue papillae, gingivitis
Vitamin B_{12}	Oral signs of deficiency include glossitis; red, swollen and tender oral mucosa; atrophy of tongue papillae

3. **Relation of masticatory ability in achieving good nutrition in elderly people**

A reduced of masticatory ability possibly impacts on selection of food and intake of nutrients, which puts elderly people at risk of malnutrition. Varieties of chewing ability evaluation have been developed in order to evaluate masticatory function, composed of subjective evaluation by using questionaires or patient interviews (2, 9, 10) and objective evaluation by sieving methods (12-17), chewing gum methods (18-20), or wax cube analysis methods (21-24). However, nutritional status is assessed using dietary assessment methods (food and/or nutrient intakes), anthropometric measurement of height and weight such as body mass index (BMI), nutritional assessment tool such as the Mini Nutritional Assessment (MNA®), and biological marker such as serum albumin.

BMI may be used as an indicator of malnutrition. In the absence of illness, a low BMI suggests that energy intake dose not meet energy expenditure, whereas a high BMI suggests that energy intake exceeds energy expenditure. A higher BMI associates with compromised dentition, such as edentulous people who wear one or no denture and people without a functionally natural dentition or with many missing natural teeth without denture (33), that those people are more likely to be overweight because of over-intake of carbohydrate and fats instead of fruit and vegetables. In the other words, the situation might be different with frail elders, who live in an institution, with a dysfunctional dentition have a lower BMI than elder with better function (34). The likelihood of malnutrition, as defined by the MNA, is higher in those with fewer teeth or no dental prosthesis (35). Plasma albumin has been used widely as a biochemical indicator of nutritional status to assess the risk associated with dentition (35). However, it is too insensitive and nonspecific to make a good indicator of nutritional status (36).

Although many studies have shown that edentulous people have poorer diets than dentate people (37-39), a causative effect has not been demonstrated. Studies have generally shown that prosthetic rehabilitation in the absence of dietary counseling not lead to dietary improvement (33, 37-40). Nutritional counseling along with the provision of dentures in older adults can result in dietary improvements (41).

4. Association between dentition, masticatory ability and nutrition

The number of natural teeth and their position as opposing pairs are related to chewing ability, and people without teeth or even with dentures tend to chew less effectively with people with healthy natural teeth.

Masticatory function has been found to be significantly impaired in people who have complete or removable partial dentures as compared with those whose dentition is intact (3, 7). A higher proportion of edentulous subjects had insufficient nutrient intakes compared with dentate subjects (2). Evidence from early studies shows that loss of functional dentition and denture wearing results in selective food avoidance, especially of hard foods, such as raw fruits and vegetables and foods containing seeds and pips, such as grapes, tomatoes, and whole grain bread, that are primary sources of many essential vitamins and minerals (7, 42). Furthermore, having fewer than five pairs of opposing natural teeth in the molar region of the mouth was also found to be an independent risk factor for consumption of insufficient fruits and vegetables (25).

Improvement of chewing function with new conventional dentures or implant-supported dentures alone does not sufficient to change what people eat (40). Sandstrom and Lindquist (43) reported the measurement of changes in the intake of nutrients by patients who received new conventional dentures and those who received implant-supported prosthesis. They found an increase in consumption of fruit and vegetables and crisp bread by patients receiving implant-supported prosthesis only.

There are many factors that influence food choice, which may explain why improving chewing ability alone does not have a significant impact on diet. Factors such as attitude to healthier eating, increasing age, difficulties swallowing, cognitive decline, death of a spouse, living in an institution, physical limitations associated with age, are more important than compromised masticatory ability (10, 44, 45).

5. Effect of prosthodontics on dietary intake and nutritional status

Although dental rehabilitation may improve masticatory function, the outcome of prosthetic rehabilitation is rarely judged by what it achieves in terms of dietary improvements (40). Edentulous and partially dentate patients may be at increased risk of poor health. Impaired masticatory ability shown some effects on food choice, intake of nutrients, nutritional status and subsequent health (5, 46). For the patient with dental impairments, reaching the goals of consuming nutritious foods may be compounded by masticatory problems and therefore prosthetic rehabilitation may have an important role to play in providing the functional means to improve dietary intake (40).

Complete dentures require retention, stability, aesthetics, phonetics, and comfort, which can lead to healthy supporting tissues and make it possible to achieve patient satisfaction (47, 48). However, psychological conditions also play an important part in tooth loss when associated with the risk of a patient’s dissatisfaction.

Overdentures have become an advantageous option as treatment for patients with unfavorable edentulous ridges as they can provide retention, stability and comfort (49, 50). These requirements are managed by following the same technical-scientific principles of complete dentures, added to a system of retention obtained by different connectors attached to the implants, such as O-ring, magnetic and bar with clips. The efficiency achieved in the retention and stability of overdentures provides a degree of satisfaction that permits a better performance in mastication, even with patients where their overdentures have poor retention (51). Geertman, et al. reported that the masticatory muscles respond to the stimulus received. The sensitivity achieved by overdentures can guarantee and integrate muscle reaction, which makes it possible to chew food more effectively. The ability to chew mainly tough food depends on the retention offered by implants placed in the lower jaw (51).

Masticatory efficiency is improved dramatically by implant-supported dentures (52). However, improved masticatory efficiency does not necessarily lead to improvements in intake of nutrients. Comparison of diet between patients fitted with different types of prosthesis, whether implant-supported or conventional, removable, or fixed, show no nutritionally differences (40, 53). The psychological state also influences the interest of patients for food (54, 55). The necessity of a specialized as well as individualized approach has to be emphasized. The recovery of the stomatognathic system using different kinds of prosthesis, does not necessarily provide changes in feeding habits by themselves (43). Overdentures are clearly indicated for elderly patients that had lost their functional ability or when they had not been able to adapt to a complete denture in the lower jaw (47, 56).

The effect of dentures on nutritional status varies among individuals (43, 57). Some people compensate for reduced masticatory ability by choosing processed or cooked foods rather than fresh and by chewing longer before swallowing and others may eliminate entire food groups from their diets (3, 7). Nutrient intakes of individuals with impaired dentition can fall below minimum requirements if an already poor eating pattern received some sudden impacts such as illness, loss of taste, inability to chew, or changes in economic status and living situation (5, 46).

When dental status causes change in food habits, nutritional status can suffer. The number of oral problems, including limited chewing ability, was the most important predictor of weight loss. As the degree of dental impairment increases, diet quality seems to decrease (57). In a large group of free-living elders, inferior diets were associated with denture wearing, low income, and low educational status. Those elder who were wearing one or two complete dentures had a 20% decline in the nutrient quality of their diets compared with dentate persons (27). Also, intake of vitamin A, fiber, and calcium declined as the number of teeth decreased. Dentate adults tend to eat more fruits and vegetables than full-denture wearers (58).

Replacing ill-fitting dentures with new ones does not necessarily result in significant improvements in dietary intake (54). Similarly, exchanging optimal complete dentures for implant-supported dentures has not resulted in significant improvement in food selection or nutrient intake (43, 53, 59).

Poor oral function also linked to decreased self-esteem and a decline in the quality of life (60). Adults with missing teeth or loose dentures may avoid certain social activities because they are embarrassed to speak, smile, or eat in front of others.

Changes in food habits associated with denture wearing may also affect general health. Among a healthy, well-educated group, denture wearers also consumed more refined carbohydrates and sucrose than dentate adults (27). The types of foods chosen were related to oral functional characteristics. Those with poor oral function had a low-fiber diet, resulting in a semisolid or soft consistency of the alimentary bolus. This form of bolus may be the origin of some gastric disorders (43). Also, the use of gastrointestinal drugs appears to be higher in adult edentulous subjects with poor masticatory ability (27).

Due to many factors as previous described, elderly patients may have malnutrition-induced deterioration of health before exhibiting signs of clinical malnutrition. It is important to early detect malnutrition risk in elders because it is difficult to improve nutritional status after it has deteriorated (27). Dentist should be aware of the nutritional risk of the dentally compromised patients and the consequences of this in terms of health and well being (40). In conclusion, to improve nutritional status, patients should receive customized dietary advice when receiving new fixed or removable dentures to promote favorable changes to their dietary habits (41).

CHAPTER III

MATERIALS AND METHODS

Development of wax cubes hardness

A two-colored (red/white) wax cube used in previous studies (23, 24) was made of 70% by weight of Bee wax and 30% by weight of Microcrystalline wax. Two new formulations of wax cube, a softer wax cube (50% of Bee wax and 50% of Microcrystalline wax) and a harder wax cube (85% of Bee wax and 15% of Microcrystalline wax) were developed with different color. The color used in this study was a food grade oil-based dye (Blue; Lake Brilliant Blue, Red; Lake Ponceau 4R, Yellow; Lake Tartrazine, Vinayak Corporation, Mumbai, India).

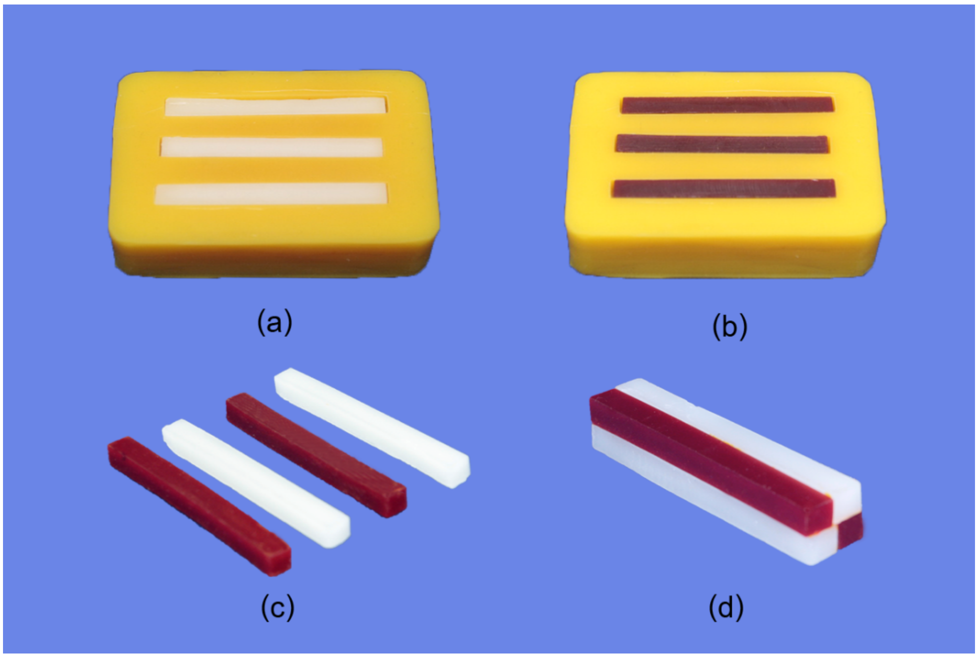


Fig.1 The blended wax

(a) White bar's mold (b) Red bar's mold

(c) The wax bars (d) The 10 mm x 10 mm x 50 mm wax bar

The wax bars were made by poured the molten wax into silicone molds (Fig.1a, b and c). Four pieces of the wax bars were placed alternating in red and white colors to create a 10 mm x 10mm x 50 mm wax bar (Fig.1d), then the wax bar were cut to make a 10 mm x 10 mm x 5 mm wax pattern. Next, two wax patterns were combined together after rotating 90 degrees, in order to make an alternating color scheme. From this step, the 10 mm x 10 mm x 10 mm wax cubes were obtained in different color (Fig.2).

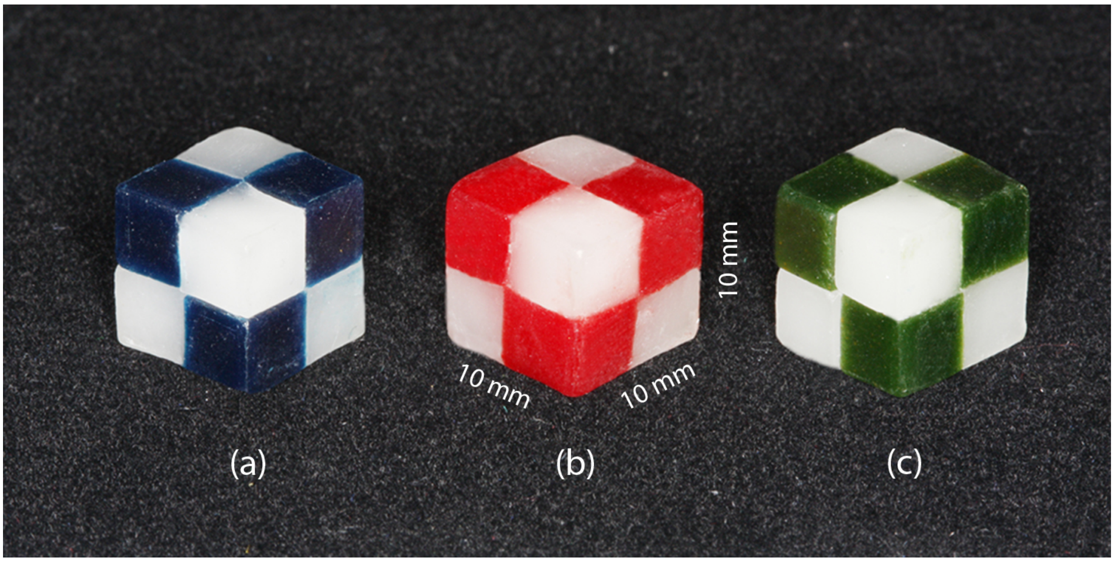


Fig.2 Size and shape of developed wax cube;

(a) Hard wax cube, (b) Original wax cube, (c) Soft wax cube

The wax cubes were disinfected by exposure to concentrated 350 mg/l ethylene oxide gas at 37°C for 5 hours (Steri-Vac4XL, 3M. United States), then the wax cubes were left for 24 hours until the ethylene oxide had vaporized. They were stored at 5°C until used.

Sixteen common foods, that were boiled Chinese kale, fresh apple, boiled baby corn, fresh guava, boiled pumpkin, boiled fish ball, boiled Chinese cabbage, cooked jasmine rice, boiled pork, hard-boiled egg, fresh cow-pea, boiled cow-pea, plain omelet, fried fish, fresh cucumber and fried pork, were selected for represent the most frequently consume foods by Thai elderly patients interview. Hardness test of 10 pieces of each wax cube's hardness and 10 pieces of each common foods, which prepared in 10 x 10 x 10 mm size, were made with Universal Testing Machine (SHIMADZU EZTest®, SHIMADZU Corporation, Tokyo, Japan) (Fig.3) with a circular plate (diameter 100 mm.) at 75% of compression with constant cross-head speed of 10 mm/min (Fig.4) (61). Mean maximal peak forces from the 10 pieces of each test item were used for statistical analyses of hardness.

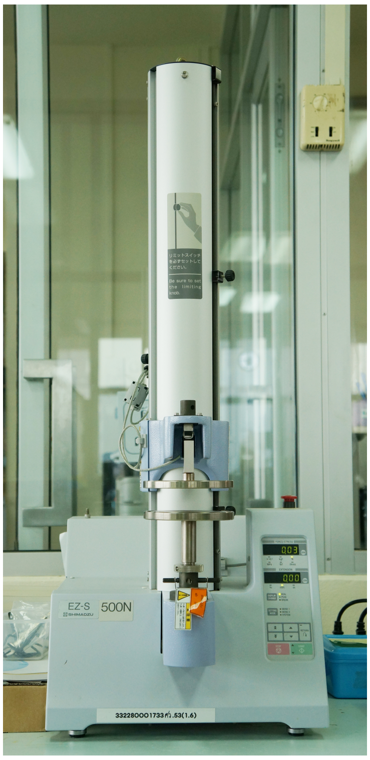


Fig.3 Universal Testing Machine (SHIMADZU EZTest®)

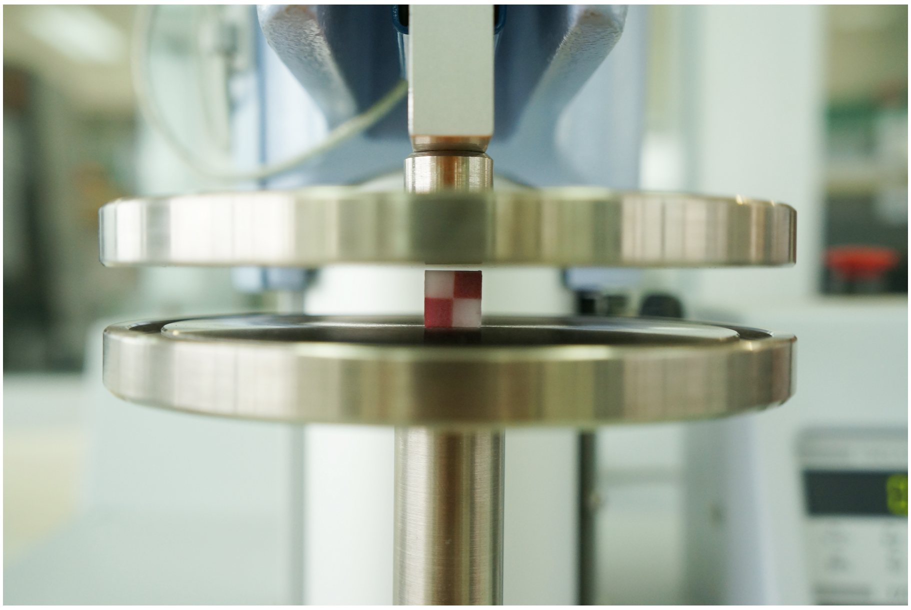


Fig.4 Hardness test with a circular plate

Subjects

Subjects of this study consisted of 3 groups of Thais that were selected to participate based on the following criteria:

Group 1 was twenty normal dentition subjects (students and staff of Faculty of Dentistry) who had at least 1 premolar and 1 molar per quadrant (occluding pairs were counted as 2 occlusal units).

Group 2 was twenty totally edentulous subjects (routine follow-up patients of the Graduated Clinic, Department of Prosthodontics, Faculty of Dentistry, Chulalongkorn University) with complete dentures.

Group 3 was twenty totally edentulous subjects (routine follow-up patients of the Graduated Clinic, Department of Prosthodontics, Faculty of Dentistry, Chulalongkorn University) with 2 implant-retained lower complete dentures.

The subjects in group 2 and group 3 had received their dentures from the above clinic and had used them for 1 to 3 month before investigation. At the time of investigation, the dentures showed satisfactory stability and acceptable retention. The subjects were using their dentures regularly, during daytime and when eating, and were thus considered to be well adapted to wearing dentures. All experimental procedures and tests were approved by the Ethics Committee of Chulalongkorn University on October 12th, 2010. Each subject signed informed consent prior to the beginning of the study.

Chewing Ability evaluation

The wax cubes (10x10x10 mm) were kept in an incubator (Contherm160M, Contherm Scientific Ltd., New Zealand) at 37°C for 24 hours and soaked in a water bath (Isotemp202, Fisher Scientific Co., Ltd, Japan) at 37°C for further 10 minutes prior to the test. Each subject's chewing ability was evaluated using all three hardness in the same visit in the order of system hard, original, and then soft wax cube.

The subject sat in an upright position on the dental unit and was instructed to chew three pieces of each hardness of wax cube, one cube by another for 10 chewing strokes under habitually chewing pattern. The chewed wax was removed from the oral cavity of the subject (Fig.5), rinsed under tap water for 20 seconds, and soaked in 70 percent concentration of ethyl alcohol for 5 minutes.

Fig.5 The chewed wax after 10 chewing strokes.

Images of both sides of the chewed wax were captured by the digital camera (Canon EOS 450D, Canon Inc., Tokyo, Japan) with a macro lens (Canon macro 100 mm) under standardized lighting conditions (a photo stand kit; Copy stand CS920 and Copy light CL-150 with 2 light bulbs; Philips® Cool Daylight 125 Watts, Color temperature 6,500 K and a lux meter; DigiconLX-70, Protonics Inter-trade Co, Ltd., Thailand) (Fig.6).

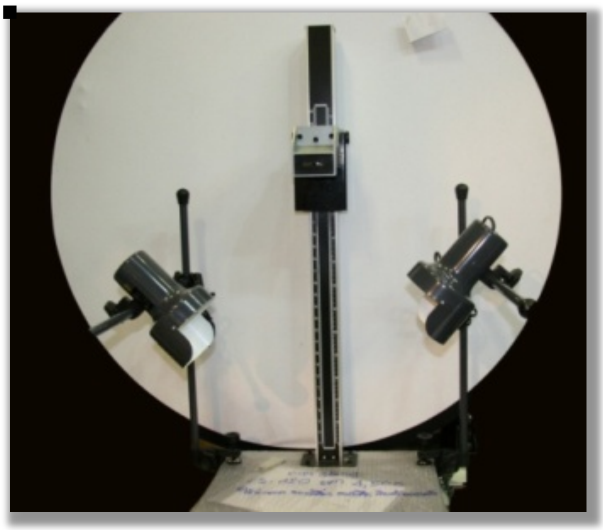


Fig.6 The photo stand kit

All images were transferred and analyzed by Image J program (Version 1.42Q, NIH, MD, USA) (Fig.7). For example with the original wax cube, the standard color value that representing well mixed red and white color wax was obtained by mixing an equal amount (by weight) of red wax and white wax until a uniform color of the mixture was achieved. Then an image of the mixture was captured and analyzed by the Image J program to define color into specific color value (23).

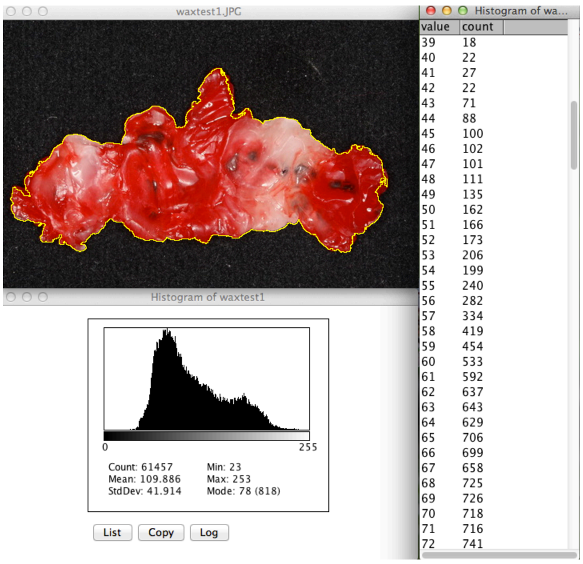
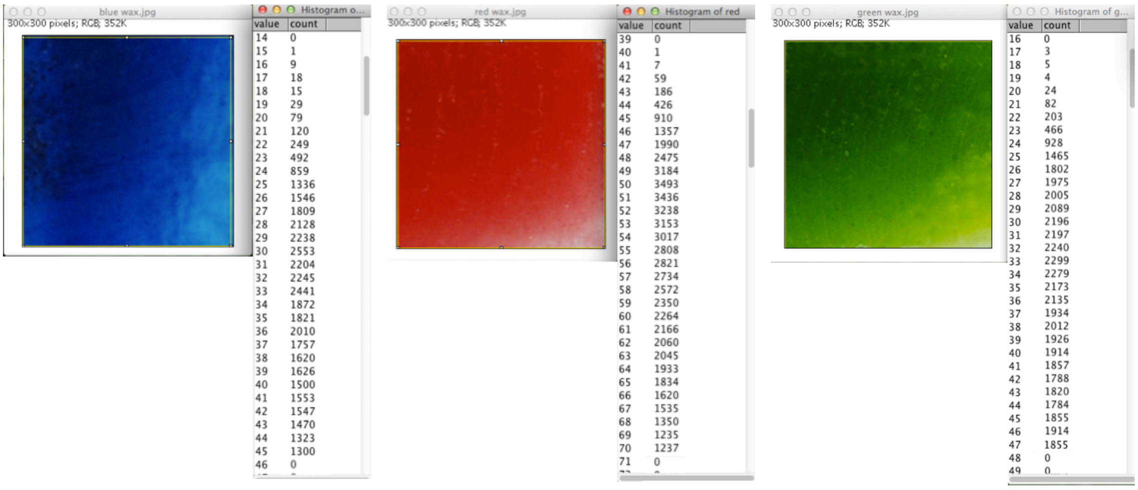


Fig.7 Image J Program

The Image J program was used to define color into specific color value; ranging between 0 (white color) to 255 (black color) (23). The program also calculated number of color values, as well as number of pixels within the define area with wand tool. After the analyzing process, Image J program showed the standard color value of the original wax cube was in the range of 40-70. By the same process, the hard wax cube and the soft wax cube showed standard color value in the range of 15-45 and 17-47, respectively (Fig.8).



(a) (b) (c)

Fig.8 The standard color value of the wax cubes analyzed by the Image J program

(a) The hard wax cube showed standard color value in the range of 15-45

(b) The original wax cube showed standard color value in the range of 40-70

(c) The soft wax cube showed standard color value in the range of 17-47

(a)

(b)

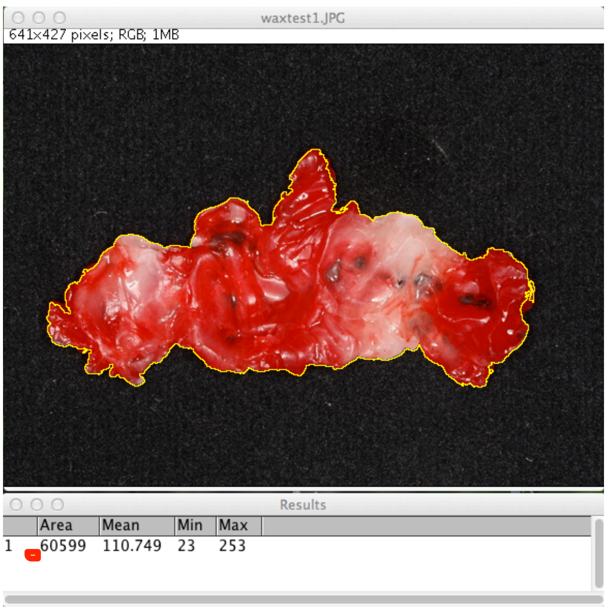


Fig.9 Total number of pixels of the chewed wax using Image J Program

(a) The defined area with wand tool

(b) Total number of pixels of the chewed wax by the measure function

The chewing ability evaluation was done as follows: (1) the pictures of the chewed waxes were analyzed using the measure function of the Image J program to find the total number of pixels of the pictures (Fig.9); (2) the pictures of the chewed waxes were analyzed again using the color histogram function of the Image J program to define the number of pixels which resulted in the standard color values (Fig.10); (3) the percentage of chewing ability was computed by the following formula as below:

$$\text{The percentage of chewing ability} = \frac{\text{Total number of pixels of standard color value}}{\text{Total number of pixels of the chewed wax}} \times 100$$

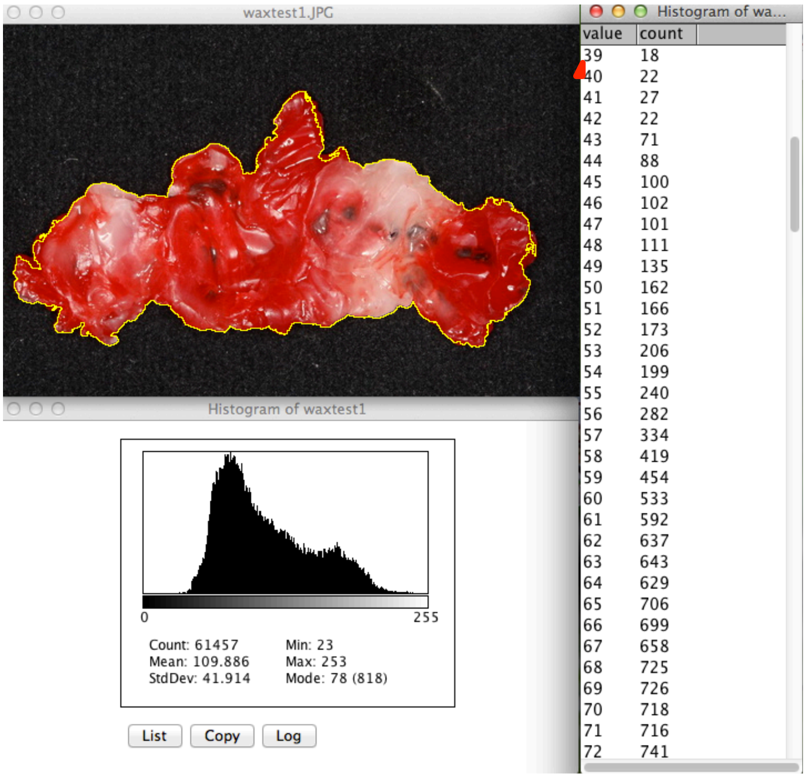


Fig.10 Total number of pixels of standard color value using the color histogram function of the Image J program

Each subject generated six surfaces (from three wax cubes) of the chewed wax for each hardness, therefore, the average value was calculated in order to determine the average "percentage of chewing ability" of each subject then interpret the relation between hardness and percentage of chewing ability.

Statistical analysis

Means and standard deviations (SD) of age of the subjects, percentage of chewing ability, hardness scores of the wax cubes and selected common foods were analyzed. Two-way analysis of variance (ANOVA) and Post-hoc multiple comparison tests were used to compared the results of three types of hardness of the wax cube and three types of dentition. Statistical analysis was performed with the Statistics Package for the Social Sciences (SPSS) version 17.0 (SPSS Incorporation, Illinois, USA). In all statistical analysis, a *P*-value less than .05 was considered significant.

CHAPTER IV

RESULTS

The developed wax cube were used to evaluate the chewing ability in three different dentition groups by using Image J program to analyze the color of the chewed wax.

The descriptive data consisted of number of subjects divided by gender among three groups of dentition and the average age (mean±SD) in years are shown in Table II

The average percentages of chewing ability (mean±SD) among three groups of dentition (normal dentition group, complete denture group and implant-retained lower complete denture group) from three hardness of wax cube are shown in Table III.

Table II Number of subjects divided by gender and the average age of the subjects among three groups of dentition.

Group	Gender		Age (years)
	Male	Female	
Normal Dentition	7	13	27.85±1.42
Complete Denture	11	9	70.55±9.14
Implant-retained Lower Complete Denture	9	11	67.70±6.68

Table III Means and standard deviations of percentage of chewing ability obtained from three hardness of the wax cube.

Sample group \ Type of chewing wax cube	Hard	Original	Soft
Normal Dentition	25.68±5.85	38.78±6.69	42.17±9.08
Complete Denture	21.89±5.82	26.00±7.33	27.68±6.04
Implant-retained Lower Complete Denture	21.28±5.30	33.30±5.66	34.73±3.25

“a” denotes statistical difference at alpha = .05

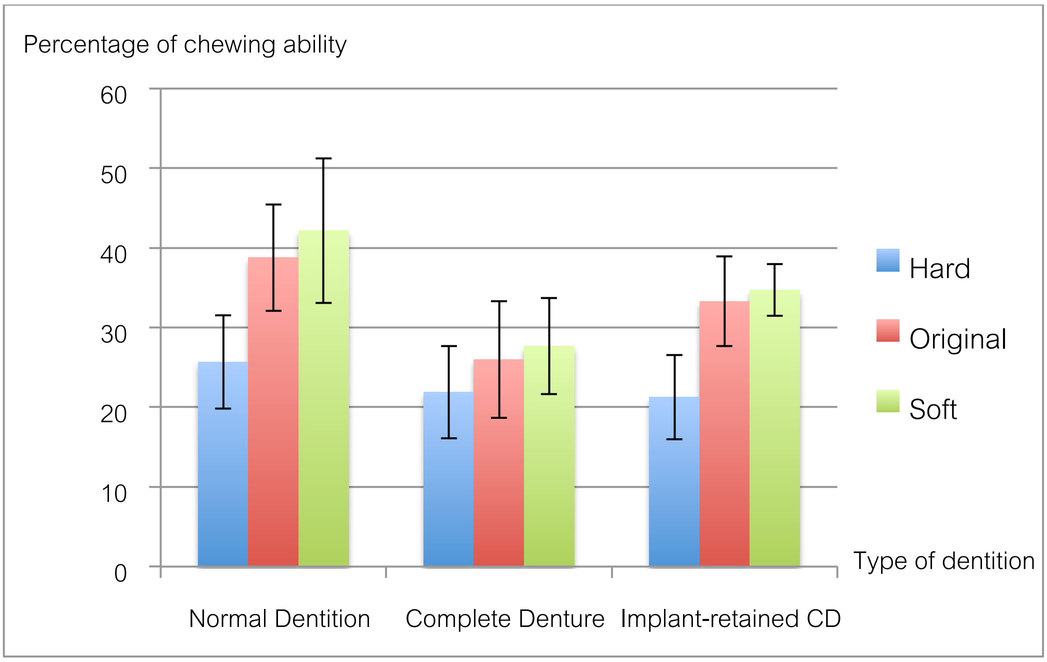


Fig.11 Percentage of chewing ability obtained from three hardness of the wax cube (vertical bars show standard deviation).

In all types of wax cube tested, the normal dentition group had higher percentage of chewing ability than implant-retained lower complete denture group and complete denture group, respectively (Fig.11). Statistical analysis showed that the data was in a normal distribution with homogeneity variances. Statistically analysis revealed a significant difference ($P < .05$) in percentage of chewing ability between groups of dentition with only original and soft wax cubes.

Means and standard deviations of hardness score (N) for each item are shown in Table III. Mean hardness scores ranged from 1.30 N for hard-boiled egg to 65.20 N for fried pork.

Table IV Means and standard deviations of hardness scores for wax cubes and selected common foods.

No.	**Item**	**mean±SD (N)**
1	Hard-boiled egg	1.30±0.11
2	Boiled fish ball	2.52±0.80
3	Boiled pumpkin	2.70±0.60
4	Fried fish	4.16±1.60
5	Cooked jasmine rice	7.78±0.82
6	Plain omelet	9.61±0.49
7	Boiled cow-pea	11.83±3.27
8	Fresh guava	19.24±5.05
9	Boiled pork	20.80±3.30
10	Boiled baby corn	28.28±3.33
11	Boiled Chinese cabbage	30.98±3.63
12	Fresh apple	32.07±4.59
13	Fresh cow-pea	32.37±8.46
14	*Soft wax cube*	41.59±4.56
15	Boiled Chinese kale	47.44±5.24
16	*Original wax cube*	50.80±2.15
17	Fresh cucumber	51.04±3.75
18	*Hard wax cube*	63.55±2.49
19	Fried pork	65.20±2.85

CHAPTER V

DISCUSSION

The results of this study indicated that complete denture group had lower chewing ability than normal dentition group for three types of the wax cube. Also, complete denture group had the percentage of chewing ability for chewing hard wax cubes lower than original and soft wax cubes, respectively. The loss of natural teeth was related to diminished nutritional intake, especially in older adults (62). A number of studies had shown that the masticatory performance of edentulous patients who have complete denture was approximately 10-20 percent as efficient as dentate subjects (17, 63). As in this present study complete denture group had reduced about 35 percent for chewing soft and original wax cubes when compare to the normal dentition group.

However, implant-retained lower complete denture group showed the higher percentage of chewing ability than complete dentures group for two types of wax cube, original and soft, except hard wax cube. These showed that edentulous patient with implant-retained lower complete denture had better chewing ability than whom with conventional complete dentures. Geertman, *et al.* (59) reported that the subjects who received mandibular two-implants overdentures rates their ability to chew tough (steak) and hard (carrot) foods significantly better than subjects who wore conventional complete dentures. This may be attributed to the additional retention provided by implants and tissue support, instead of the conventional denture treatment that has only tissue support.

Sixteen common foods used in this study were selected from the most frequently consume by patient interview. Hardness test showed that almost all of selected food had lower hardness than three types of wax cube. This may concluded that patients who wore conventional complete denture could chew all of selected food but they had reduced ability to comminute them into fine particle than their normal dentition stage.

Some studies about nutrition in adult populations (2, 7, 58) reported that adults who wore partial and complete dentures had a diet lacking in fiber and vitamins. The reasons for this were difficulty in chewing hard foods, such as raw vegetables and fresh fruits, and a decreased sense of taste. For these situations, softer and more highly flavored foods might be substituted, but such foods frequently had a lower nutritional value. The implications for general health in adults had more concerned, as poor diet might lead to deficiency in nutrients and illnesses such as osteoporosis, atherosclerosis and bowel disease (5). It was recommended by some authors that these patients should receive dietary counseling as part of their prosthodontics rehabilitation (64). However, some fresh fruits and raw vegetables were difficult for denture-wearers to eat, but these problems could be overcome with food preparation (65).

Nutrition was not only a matter of masticatory function, but also depended on other influencing factors. A complexity of problems including social, financial, and functional barriers to achieving adequate food intake contributed to malnutrition in elderly people (25, 66). Prosthetic treatment alone was not adequate to attain a significant improvement in the nutritional status of dentally compromised elderly patients (66). There were some tools available for assessing the presence and severity of undernutrition in frail elders such as the Mini Nutritional Assessment (MNA®) developed by Nestle' Nutrition or body mass index (BMI). However, the two-colored wax cube could be utilized in evaluation of chewing ability. There could be the one option for screening chewing ability accompanied by some nutritional assessment tools to evaluate nutritional status of elderly patients.

Table 2 showed that normal dentition group had the percentage of chewing ability for chewing original and soft wax cube about 30-40%. So, if the patients could chew these wax cubes to 30%, we assumed that those patients could chew all of selected common food as well. Even though inclusion criteria of normal dentition group were the subjects who had at least 1 premolar and 1 molar per quadrant (occluding pairs were counted as 2 occlusal units in each side), but all subjects who were participated in the study had more than 1 premolar and 1 molar per quadrant and had until the second molar. Also, the number of occluding pairs might effect on chewing ability as seen in high level of standard deviation.

However, the original and soft wax cubes were the most suitable hardness for chewing ability in total edentulous patients. Results obtained from hardness test showed that the average hardness of only original and soft wax cubes was approximate to the range of selected common foods but the hard wax cube hardness is too far beyond chewing and cannot identify the different between groups of patient. Food texture was complex attribute which composed of mechanical, geometrical and other perceptional characteristics (67). In this study, only hardness was evaluated among many mechanical characteristics of food texture. Other characteristics such as cohesiveness, toughness and chewiness remain to be compared with other common foods in further study.

The two-colored wax cube has many advantages due to its simplicity. The entire processes from chewing to process with the Image J program can be done about 30 minutes. Also, these can be done with a limited budget about 5 Baht per piece when compared with Japanese wax cube which cost about 100 yen (37-38 Baht) per piece.

As a result, the developed method can be utilized clinically to evaluate chewing ability after dental treatment.

In conclusion, the development of hardness of the two-colored wax cube in Thailand has many advantages for chewing ability evaluation especially in total edentulous patients. Results of percentage of chewing ability from difference hardness of the wax cube may lead us to advice the total edentulous or elderly patients choose some suitable foods as equal to their ability when comparing their hardness with the wax cube and select food items to meet the nutritional values as recommended for daily intake. However, the two-colored wax cube is the one option for evaluate the chewing ability after denture delivery in 3-dimensions but should develop the short process of both manufacturing and analyzing. In this study, only the complete denture was evaluated among many factors of chewing ability. Other factors such as type of edentulous ridge, type of occlusal scheme or systemic disease of the subjects remain to be compared in further studies.

CHAPTER VI

CONCLUSIONS

From the results of the present study, it can be concluded that

1. The two-colored wax cube can be developed into different levels of hardness.
2. The developed wax cube can be utilized in evaluation of chewing ability. Totally edentulous patients with conventional complete denture group have reduced the percentage of chewing ability but implant-retained lower complete denture groups showed the higher percentage of chewing ability than complete dentures group.
3. The original and soft wax cubes are the most suitable hardness for chewing ability in total edentulous patients because the average hardness of only original and soft wax cubes are approximate to the range of selected common foods and can identify the different between groups of patient.
4. Comparison of hardness of wax cubes and common foods, most common foods are in the range that complete denture patients can chew.
5. The two-colored wax cube is the one option for screening chewing ability accompanied by some nutritional assessment tools to evaluate nutritional status of elderly patients.

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APPENDIX

APPENDIX

Contents Pages

Descriptive statistic analysis in percentage of chewing ability of normal dentition group

Descriptives

	WaxType			Statistic	Std. Error
percentage	Soft wax	Mean		42.1700	2.03037
		95% Confidence Interval for Mean	Lower Bound	37.9204	
			Upper Bound	46.4196	
		5% Trimmed Mean		42.1489	
		Median		41.4000	
		Variance		82.448	
		Std. Deviation		9.08009	
		Minimum		26.83	
		Maximum		57.89	
		Range		31.06	
		Interquartile Range		14.17	
		Skewness		.083	.512
		Kurtosis		-.970	.992
	Medium wax	Mean		38.7800	1.49492
		95% Confidence Interval for Mean	Lower Bound	35.6511	
			Upper Bound	41.9089	
		5% Trimmed Mean		38.8361	
		Median		38.4450	
		Variance		44.696	
		Std. Deviation		6.68548	
		Minimum		26.19	
		Maximum		50.36	
		Range		24.17	
		Interquartile Range		8.52	
		Skewness		-.145	.512
		Kurtosis		-.260	.992

	Hard wax	Mean		25.6820	1.30919
		95% Confidence Interval for Mean	Lower Bound	22.9418	
			Upper Bound	28.4222	
		5% Trimmed Mean		25.7356	
		Median		25.1600	
		Variance		34.280	
		Std. Deviation		5.85490	
		Minimum		15.22	
		Maximum		35.18	
		Range		19.96	
		Interquartile Range		11.51	
		Skewness		.112	.512
		Kurtosis		-.964	.992

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	WaxType	Statistic	df	Sig.	Statistic	df	Sig.
percentage	Soft wax	.096	20	.200*	.968	20	.709
	Medium wax	.119	20	.200*	.963	20	.600
	Hard wax	.128	20	.200*	.954	20	.432

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Descriptive statistic in percentage of chewing ability of complete denture group

Descriptives

	WaxType			Statistic	Std. Error
percentage	Soft wax	Mean		27.6770	1.35074
		95% Confidence Interval for Mean	Lower Bound	24.8499	
			Upper Bound	30.5041	
		5% Trimmed Mean		27.5033	
		Median		26.8050	
		Variance		36.490	
		Std. Deviation		6.04071	
		Minimum		19.19	
		Maximum		39.29	
		Range		20.10	
		Interquartile Range		9.39	
		Skewness		.600	.512
		Kurtosis		-.584	.992
	Medium wax	Mean		26.0040	1.63865
		95% Confidence Interval for Mean	Lower Bound	22.5743	
			Upper Bound	29.4337	
		5% Trimmed Mean		25.6250	
		Median		25.9500	
		Variance		53.704	
		Std. Deviation		7.32829	
		Minimum		16.11	
		Maximum		42.72	
		Range		26.61	
		Interquartile Range		9.66	
		Skewness		.854	.512
		Kurtosis		.364	.992

	Hard wax	Mean		21.8925	1.30116
		95% Confidence Interval for Mean	Lower Bound	19.1691	
			Upper Bound	24.6159	
		5% Trimmed Mean		21.4378	
		Median		20.7600	
		Variance		33.860	
		Std. Deviation		5.81897	
		Minimum		13.35	
		Maximum		38.62	
		Range		25.27	
		Interquartile Range		6.72	
		Skewness		1.222	.512
		Kurtosis		2.473	.992

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	WaxType	Statistic	df	Sig.	Statistic	df	Sig.
percentage	Soft wax	.152	20	.200*	.932	20	.170
	Medium wax	.127	20	.200*	.929	20	.145
	Hard wax	.137	20	.200*	.919	20	.096

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Descriptive statistic in percentage of chewing ability of implant-retained lower complete denture group

Descriptives

	WaxType			Statistic	Std. Error
percentage	Soft wax	Mean		34.7270	.72725
		95% Confidence Interval for Mean	Lower Bound	33.2048	
			Upper Bound	36.2492	
		5% Trimmed Mean		34.8728	
		Median		34.7150	
		Variance		10.578	
		Std. Deviation		3.25238	
		Minimum		26.66	
		Maximum		40.17	
		Range		13.51	
		Interquartile Range		3.57	
		Skewness		-.698	.512
		Kurtosis		1.062	.992
	Medium wax	Mean		33.3030	1.26550
		95% Confidence Interval for Mean	Lower Bound	30.6543	
			Upper Bound	35.9517	
		5% Trimmed Mean		32.9683	
		Median		32.1550	
		Variance		32.030	
		Std. Deviation		5.65948	
		Minimum		24.75	
		Maximum		47.88	
		Range		23.13	
		Interquartile Range		5.02	
		Skewness		1.363	.512
		Kurtosis		2.546	.992

	Hard wax	Mean		21.2765	1.18468
		95% Confidence Interval for Mean	Lower Bound	18.7969	
			Upper Bound	23.7561	
		5% Trimmed Mean		21.4522	
		Median		22.0450	
		Variance		28.069	
		Std. Deviation		5.29803	
		Minimum		10.02	
		Maximum		29.37	
		Range		19.35	
		Interquartile Range		5.53	
		Skewness		-.543	.512
		Kurtosis		.130	.992

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	WaxType	Statistic	df	Sig.	Statistic	df	Sig.
percentage	Soft wax	.124	20	.200*	.958	20	.513
	Medium wax	.128	20	.200*	.954	20	.432
	Hard wax	.157	20	.200*	.944	20	.290

a. Lilliefors Significance Correction

*. This is a lower bound of the true significance.

Statistical analysis for differences in percentage of chewing ability between groups of dentition

Univariate Analysis of Variance

Between-Subjects Factors

		Value Label	N
Dentition	1	Normal Dentition	60
	2	CD	60
	3	Implant-retained CD	60
WaxType	1	Soft wax	60
	2	Medium wax	60
	3	Hard wax	60

Levene's Test of Equality of Error Variances[a]

Dependent Variable:percentage

F	df1	df2	Sig.
2.798	8	171	.006

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Dentition + WaxType + Dentition * WaxType

Tests of Between-Subjects Effects

Dependent Variable:percentage

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	8800.762[a]	8	1100.095	27.799	.000
Intercept	163819.480	1	163819.480	4139.703	.000
Dentition	3229.775	2	1614.887	40.808	.000
WaxType	4828.795	2	2414.397	61.012	.000
Dentition * WaxType	742.193	4	185.548	4.689	.001
Error	6766.941	171	39.573		
Total	179387.184	180			
Corrected Total	15567.703	179			

a. R Squared = .565 (Adjusted R Squared = .545)

Oneway

Test of Homogeneity of Variances

percentage

WaxType	Levene Statistic	df1	df2	Sig.
Soft wax	10.423	2	57	.000
Medium wax	1.033	2	57	.362
Hard wax	.242	2	57	.786

ANOVA

percentage

WaxType		Sum of Squares	df	Mean Square	F	Sig.
Soft wax	Between Groups	2100.985	2	1050.493	24.333	.000
	Within Groups	2460.809	57	43.172		
	Total	4561.794	59			
Medium wax	Between Groups	1643.327	2	821.664	18.899	.000
	Within Groups	2478.155	57	43.476		
	Total	4121.483	59			
Hard wax	Between Groups	227.655	2	113.827	3.549	.035
	Within Groups	1827.977	57	32.070		
	Total	2055.632	59			

percentage

WaxType		Statistic[a]	df1	df2	Sig.
Soft wax	Brown-Forsythe	24.333	2	38.674	.000
Medium wax	Brown-Forsythe	18.899	2	54.712	.000
Hard wax	Brown-Forsythe	3.549	2	56.558	.035

a. Asymptotically F distributed.

Post Hoc Tests

Multiple Comparisons

Dependent Variable:percentage

WaxType		(I) Dentition	(J) Dentition	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Soft wax	Bonferroni	Normal Dentition	CD	14.49300*	2.07779	.000	9.3677	19.6183
			Implant-retained CD	7.44300*	2.07779	.002	2.3177	12.5683
		CD	Normal Dentition	-14.49300*	2.07779	.000	-19.6183	-9.3677
			Implant-retained CD	-7.05000*	2.07779	.004	-12.1753	-1.9247
		Implant-retained CD	Normal Dentition	-7.44300*	2.07779	.002	-12.5683	-2.3177
			CD	7.05000*	2.07779	.004	1.9247	12.1753
	Tamhane	Normal Dentition	CD	14.49300*	2.43863	.000	8.3604	20.6256
			Implant-retained CD	7.44300*	2.15669	.006	1.9052	12.9808
		CD	Normal Dentition	-14.49300*	2.43863	.000	-20.6256	-8.3604
			Implant-retained CD	-7.05000*	1.53408	.000	-10.9354	-3.1646

		Implant-retained CD	Normal Dentition	-7.44300*	2.15669	.006	-12.9808	-1.9052
			CD	7.05000*	1.53408	.000	3.1646	10.9354
Medium wax	Bonferroni	Normal Dentition	CD	12.77600*	2.08510	.000	7.6327	17.9193
			Implant-retained CD	5.47700*	2.08510	.033	.3337	10.6203
		CD	Normal Dentition	-12.77600*	2.08510	.000	-17.9193	-7.6327
			Implant-retained CD	-7.29900*	2.08510	.003	-12.4423	-2.1557
		Implant-retained CD	Normal Dentition	-5.47700*	2.08510	.033	-10.6203	-.3337
			CD	7.29900*	2.08510	.003	2.1557	12.4423
	Tamhane	Normal Dentition	CD	12.77600*	2.21810	.000	7.2340	18.3180
			Implant-retained CD	5.47700*	1.95864	.024	.5790	10.3750
		CD	Normal Dentition	-12.77600*	2.21810	.000	-18.3180	-7.2340
			Implant-retained CD	-7.29900*	2.07043	.004	-12.4853	-2.1127
		Implant-retained CD	Normal Dentition	-5.47700*	1.95864	.024	-10.3750	-.5790
			CD	7.29900*	2.07043	.004	2.1127	12.4853
Hard wax	Bonferroni	Normal Dentition	CD	3.78950	1.79080	.116	-.6279	8.2069
			Implant-retained CD	4.40550	1.79080	.051	-.0119	8.8229

		CD	Normal Dentition	-3.78950	1.79080	.116	-8.2069	.6279
			Implant-retained CD	.61600	1.79080	1.000	-3.8014	5.0334
		Implant-retained CD	Normal Dentition	-4.40550	1.79080	.051	-8.8229	.0119
			CD	-.61600	1.79080	1.000	-5.0334	3.8014
	Tamhane	Normal Dentition	CD	3.78950	1.84581	.134	-.8206	8.3996
			Implant-retained CD	4.40550	1.76563	.050	-.0063	8.8173
		CD	Normal Dentition	-3.78950	1.84581	.134	-8.3996	.8206
			Implant-retained CD	.61600	1.75968	.980	-3.7807	5.0127
		Implant-retained CD	Normal Dentition	-4.40550	1.76563	.050	-8.8173	.0063
			CD	-.61600	1.75968	.980	-5.0127	3.7807

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

BIOGRAPHY

NAME	Miss Sirilada Liangbunyaphan
DATE OF BIRTH	9 January 1982
PLACE OF BIRTH	Bangkok, Thailand
INSTITUTIONS ATTENDED	Chulalongkorn University, 2000 – 2006:
	Doctor of Dental Surgery
	Chulalongkorn University, 2009 – 2011:
	Master of Science (Prosthodontics)
WORK EXPERIENCE	2006 – present, Bangsaphan-noi Hospital
	Prachuapkirikhan, Thailand
	Position: Dentist
PUBLISHED JOURNAL	"A Comparative Study of Chewing Efficiency
	Using 3 Evaluation Methods"
	J Dent Assoc Thai 2011; 61(3), 176-182
RESEARCH GRANT	The Excellent Center for Oral and Maxillofacial
	Reconstruct Project, Chulalongkorn University
CONTACT ADDRESS	459 Prannok Road, Banchanglor, Bangkok-noi,
	Bangkok 10700, Thailand
	E-mail: tuggyja@hotmail.com