การศึกษาในห้องปฏิบัติการแสดงความต้านทานการสึกของซี่ฟันเทียม

นาย พีร สุวรรณรูป

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาทันตกรรมประดิษฐ์ ภาควิชาทันตกรรมประดิษฐ์
คณะทันตแพทยศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2554

IN VITRO WEAR RESISTANCE OF ARTIFICIAL DENTURE TEETH

Mr. Pii Suwannaroop

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Prosthodontics
Department of Prosthodontics
Faculty of Dentistry
Chulalongkorn University
Academic Year 2011

Thesis Title	IN VITRO WEAR RESISTANCE OF ARTIFICIAL DENTURE TEETH
By	Mr. Pii Suwannaroop
Field of Study	Prosthodontics
Thesis Advisor	Associate Professor Mansuang Arksornnukit, 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 Morakot Piemjai, Ph.D.)

…………………………..…… Thesis Advisor
(Associate Professor Mansuang Arksornnukit, Ph.D.)

…………………………..…… Examiner
(Assistant Professor Prarom Salimee, Ph.D.)

…………………………..…… External Examiner
(Professor Hidekazu Takahashi, Ph.D.)

พีร สุวรรณรูป : การศึกษาในห้องปฏิบัติการแสดงความต้านทานการสึกของซี่ฟันเทียม (IN VITRO WEAR RESISTANCE OF ARTIFICIAL DENTURE TEETH)
อ. ที่ปรึกษาวิทยานิพนธ์หลัก : รศ.ทพ.ดร.แมนสรวง อักษรนุกิจ, 40 หน้า.

บทนำ ความต้านทานการสึกของซี่ฟันเทียมเป็นคุณสมบัติทางกลที่มีความสำคัญปัจจัยหนึ่ง ซึ่งมีอิทธิพลต่ออายุและการใช้งานของฟันเทียมแบบถอดได้ คุณสมบัติของซี่ฟันเทียมที่จะสามารถคงความสัมพันธ์ด้านบดเคี้ยวของฟันเทียมแบบถอดได้ขึ้นกับคุณสมบัตินี้ แต่การศึกษาในด้านการสึกเฉพาะในชั้นนอกสุดของซี่ฟันเทียมยังคงเป็นเรื่องยากและมีข้อสงสัยอยู่ ดังนั้นวัตถุประสงค์ของการศึกษานี้เป็นการประเมินหาความต้านทานการสึกของซี่ฟันเทียมในชั้นใต้ต่อชั้นเคลือบฟัน

วัสดุและวิธีการ ซี่ฟันเทียมทั้ง 4 ชนิดที่ใช้ในการทดสอบประกอบด้วย ซี่ฟันเทียมชนิดไม่ได้ปรับปรุงคุณสมบัติ 3 ยี่ห้อคือ คอสโมเอ็ชเอกซ์แอล เมเจอร์เดนท์ และยามาฮาชิเอฟเอกซ์ ซี่ฟันเทียมเรซินอะคริลิกชนิดมีการเชื่อมโยงข้ามในปริมาณที่สูง 1 ยี่ห้อคือ ทรูไบท์ไบโอฟอร์มไอพีเอ็น ซี่ฟันเทียมเรซินคอมโพสิต 2 ยี่ห้อคือ เอสอาร์ออโทสิทพีอี และยามาฮาชิพีเอกซ์ ซี่ฟันเทียมพอซ์เลน 1 ยี่ห้อคือ เอซทีธ ซี่ฟันเทียมที่ถูกตัดเป็นแผ่นจะถูกทดสอบในชั้นใต้ต่อชั้นเคลือบฟัน การทดสอบแบบการสึกสองวัตถุดัดแปลงจากวิธีการหมุดและจาน (15 นิวตัน 1,000 รอบต่อนาที 10,000 รอบ) วัสดุคู่สบคืออลูมิเนียมออกไซด์ วัดการสึกในรูปปริมาตรและน้ำหนักที่หายไป วิเคราะห์ข้อมูลทางสถิติโดยการวิเคราะห์ความแปรปรวนแบบทางเดียวและการเปรียบเทียบชนิดแทมฮาน หาความสัมพันธ์เชิงเส้นระหว่างปริมาตรและน้ำหนักที่หายไป

ผลการศึกษา ปริมาณการสึกของซี่ฟันเทียม คอสโมเอ็ชเอกซ์แอล เมเจอร์เดนท์ ยามาฮาชิเอฟเอกซ์ ทรูไบท์ไบโอฟอร์มไอพีเอ็น เอสอาร์ออโทสิทพีอี ยามาฮาชิพีเอกซ์ และเอซทีธ ในรูปปริมาตรที่หายไปมีค่า 0.210±0.078 0.071±0.043 0.054±0.016 0.693±0.197 0.040±0.009 0.056±0.019 และ 0.054±0.008 ลูกบาศก์มิลลิลิตรตามลำดับ และในรูปน้ำหนักที่หายไปมีค่า 0.8±0.3 0.2±0.1 0.2±0.1 1.4±0.2 0.3±0.1 0.3±0.1 และ 0.2±0.2 มิลลิกรัม ตามลำดับ การสึกของซี่ฟันเทียมชนิดมีการเชื่อมโยงข้ามในปริมาณที่สูงมีค่าสูงกว่าซี่ฟันทุกกลุ่มอย่างมีนัยสำคัญทางสถิติ ($p<0.001$) ซี่ฟันเทียมแบบพอซ์เลนและเรซินคอมโพสิตไม่ได้แสดงค่าความต้านทานการสึกที่สูงกว่าอย่างชัดเจนเมื่อเทียบกับซี่ฟันเทียมชนิดไม่ได้ปรับปรุงคุณสมบัติ พบความสัมพันธ์ระหว่างปริมาตรและน้ำหนักที่หายไป ($R^2=0.8165, p<0.01$)

สรุปผลการศึกษา ความต้านทานการสึกของซี่ฟันเทียมแต่ละชนิดมีค่าแตกต่างกันออกไป พบว่าความต้านทานการสึกของซี่ฟันเทียมชนิดมีการเชื่อมโยงข้ามในปริมาณที่สูงมีค่าต่ำกว่าซี่ฟันทุกกลุ่ม ไม่พบว่ามีซี่ฟันเทียมชนิดใดมีค่าความต้านทานการสึกดีที่สุด

ภาควิชา ..ทันตกรรมประดิษฐ์...... ลายมือชื่อนิสิต...
สาขาวิชา ..ทันตกรรมประดิษฐ์...... ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก................................
ปีการศึกษา ..2554.........................

5176125932: MAJOR PROSTHODONTICS

KEYWORDS: WEAR RESISTANCE / ARTIFICIAL DENTURE TEETH

PII SUWANNAROOP: IN VITRO WEAR RESISTANCE OF ARTIFICIAL DENTURE TEETH. ADVISOR: ASSOC. PROF. MANSUANG ARKSORNNUKIT, Ph.D., 40 pp.

Introduction: The wear resistance of artificial denture teeth is a very importance physical property in determining the function and service life of the removable dental prosthesis. The ability of artificial denture teeth to maintain a stable occlusal relationship over time relies upon this property, but wear testing on purely outer enamel surface is difficult and questionable. Therefore, the purpose of this study was to evaluate the wear resistance of artificial denture teeth in the sub-enamel layer.

Material and methods: Four types of artificial denture teeth consisted of 3 conventional acrylic resin teeth (Cosmo HXL, Major Dent and Yamahachi FX), 1 high cross-linked acrylic resin teeth (Trubyte Bioform IPN), 2 composite resin teeth (SR Orthosit PE and Yamahachi PX), and 1 porcelain teeth (ACE Teeth). The slap sub-enamel surface of each type was used to evaluate. The 2-body wear test was performed in custom made pin on disc apparatus (15 N, 1000 rpm, 10,000 cycles) with aluminum oxide antagonist. Volume loss and weight loss were measured. Data were statistically analyzed with 1-way ANOVA, followed by Tamhane's multiple range post hoc tests (α=.05). The generalized linear model between volume loss and weight loss was also analyzed.

Results: The wear of each artificial denture teeth: Cosmo HXL, Major Dent, Yamahachi FX, Trubyte Bioform IPN, SR Orthosit PE, Yamahachi PX; and ACE Teeth in volume loss were 0.210±0.078 0.071±0.043 0.054±0.016 0.693±0.197 0.040±0.009 0.056±0.019 and 0.054±0.008 mm^3, respectively, in weight loss were 0.8±0.3 0.2±0.1 0.2±0.1 1.4±0.2 0.3±0.1 0.3±0.1 and 0.2±0.2 mg, respectively. Wear from Trubyte Bioform IPN was significantly higher than that of others ($p<0.001$). ACE Teeth, SR Orthosit PE and Yamahachi PX were not totally demonstrated the higher wear resistance than 3 conventional acrylic resin teeth tested. There were a relationship between volume loss and weight loss.

Conclusion: Wear resistance varied among the denture tooth materials. Wear resistance of Trubyte Bioform IPN was lower than the others.

Department: Prosthodontics .... Student's Signature…………………………
Field of Study: Prosthodontics .... Advisor's Signature………………………...
Academic Year: 2011 ....

ACKNOWLEDGEMENTS

I would like to express my gratitude to all those who gave me the possibility to complete this thesis, Associate Professor Mansuang Arksornnukit, for his suggestion in conducting this research project, Mrs. Paipun Phitayanon for her kindly advices and suggestions in the statistical analysis for this experiment. Furthermore, I would like to thank the staffs at the Research Center, Chulalongkorn University for their help and kind assistance.

This research was supported by THE 90th ANNIVERSARY OF CHULALONGKORN UNIVERSITY FUND (Ratchadaphiseksomphot Endowment Fund).

CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ABBREVIATIONS	DESCRIPTIONS
N	Newton
rpm	rounds per minute
%	percent
°C	degree in Celsius
µm	micrometer
mm^3	cubic millimeter
mg	milligram
s	second
et al	et alii (and others)
fig	figure
ANOVA	analysis of variance
SD	standard deviation
α	alpha
®	registered

GPa	gigapascal
No	number
Ra	roughness
Ltd	Limited
Inc	Incorporation
R^2	coefficient of determination

CHAPTER I

INTRODUCTION

During the past century, the replacement of the lost natural teeth, caused by dental caries, periodontal diseases, oral and jaw pathologies, congenital missing, or accidents could be performed by many means. The most two common means in replacing loss natural teeth were fixed and removable dental prosthesis. A conventional removable prosthesis comprises of two important components; artificial denture teeth and a denture base.

Physical properties are the main considerations when choosing the type of artificial denture teeth in fabricating the prosthesis. The artificial denture teeth should mimic most of the anatomical and esthetical details. In addition, they should be non-toxic, non-reactive with oral soft tissues, user friendly, and inexpensive. Furthermore, among mechanical properties, wear resistance is an important property. Lack of sufficient wear resistance will result in excessive reduction in structure, resulting in loss of posterior tooth support, loss of vertical dimension of occlusion, loss of masticatory efficiency (1), alteration in the functional path of masticatory movement (2), fatigue of masticatory muscles (3), faulty tooth relationship, and loss of esthetics.

Currently there are various types of commercial artificial denture teeth available, such as porcelain teeth, conventional acrylic resin teeth, and improved acrylic resin teeth, including high cross-linked acrylic resin teeth and composite resin teeth. Porcelain teeth have many disadvantages; brittleness, prone to fracture, poor bonding, and mismatch in coefficient of thermal expansion with the acrylic denture base (4). Porcelain teeth also caused localized stress concentration underneath the denture base (5). Consequently, acrylic resin teeth are more commonly used in removable dentures.

Numerous in vitro studies have reported increased wear resistance of the improved acrylic resin teeth, high cross-linked acrylic resin teeth and composite resin teeth, compared with conventional acrylic resin teeth (6-13) but these studies did not cover new types of materials which have been recently developed. Some in vitro studies reported no significant difference in wear resistance between improved acrylic resin teeth and conventional acrylic resin teeth (14-16). There are many factors affecting the wear resistance such as wear testing mechanism, force, antagonist, chemical and abrasive medium (17). The other important factor is specimen characteristics. The artificial denture teeth are manufactured in varieties of compositions and layer designs.

Artificial denture teeth were previously divided into two different layers, enamel and dentin layer (18). This classification did not fit the newly developed artificial denture teeth. In addition to the two previously mentioned layers, an intermediate layer between the enamel and base layer, may be found in some products. Some composite resin teeth may contain two intermediate layers. Each layer of artificial denture teeth has different properties, such as hardness and monomer diffusion (19).

Moreover, the outer surface or enamel layer of artificial denture teeth is often removed by many reasons such as masticatory wear, or especially in occlusal adjustments or alterations of the occlusal scheme by the dentist. In case of complete denture, the average increase in height of incisal guide pin after processing ranged from 0-1.49 mm (20). This outer layer can be removed during selective grinding in laboratory and/or clinical remount. When artificial denture teeth of removable partial denture opposed to malposed natural teeth, the occlusal surface need to be ground to obtain maximum intercuspation. This has led to the exposure of the sub-enamel layer.

There are no consensus on specimen preparation and test area of wear testing in artificial denture teeth. Previous in vitro studies focused on the outermost layer and did not identify exact location of test. Since the enamel layer is very thin, it is difficult to confine the test area within this outer layer. With the limitation of layer thickness and the elimination of the outermost layer from the above-mentioned reasons, the sub-enamel layer was investigated in this study.

Objective

1. To evaluate and compare the wear resistance of various artificial denture teeth in the sub-enamel layer.
2. To investigate the correlation between the volume loss and weight loss.

Research scope

This in vitro study aimed to investigate the wear of artificial denture teeth. Four types, seven brands of artificial denture teeth were selected. Specimens were prepared in the same manner and tested by wear simulator (1,000 rpm, 15 N) with aluminium oxide as the antagonist. There are no lateral movement and abrasive medium. The wear was analyzed by volume loss and weight loss using profilometer and digital balance, respectively.

Agreements

All of the procedures of this in vitro study were performed by only one examiner with the same instruments and machines. The laboratory was at graduate prosthodontic clinic, 6th floor and dental materials research center, 9th floor, princess mother 93th building, Faculty of Dentistry, Chulalongkorn University. The room temperature was 25±2 °C.

Research limitations

This study was a laboratory experiment that could not completely mimic the multi-factorial oral environment. The results in this study were an alternative way to predict the clinical wear and help to understand the wear mechanism of artificial denture teeth.

Type of research

Experimental research

Proposed benefits

1. To determine the wear resistance among artificial denture teeth used in prosthodontics.
2. To be a guideline for choosing the artificial denture teeth.
3. To gain informative data which could be used in further artificial denture teeth developmental research.

Hypothesis

The null hypothesis was that wear resistance was not influenced by the composition or type of the artificial denture teeth.

CHAPTER II

LITERATURE REVIEW

Artificial denture teeth

The most important requirement of artificial denture teeth is good appearance. Ideally, it should be indistinguishable from natural teeth in shape, color and translucency. The artificial denture teeth should be low in density so that they do not increase the weight of the denture. They should be strong and tough to resist fracture, and hard enough to resist abrasive force. There should be good attachment between the artificial denture teeth and the denture base. They should be perfectly bonded to denture base (21). The materials which are commonly used for the production of artificial denture teeth are acrylic resins, modified acrylic resin and porcelain.

The majority of resin teeth are based on polymethyl methacrylate (PMMA) compositions. PMMA resins used in the fabrication of artificial denture teeth are similar to those used in denture base materials. Nevertheless, the degree of cross-linking within artificial denture teeth is greater than that of polymerized denture base. This increase is archived by elevating the amount of cross-linking agent. The resultant polymer displays enhanced stability and improved clinical properties (4). Various manufacturers have thus developed resins to improve wear resistance by using a high degree of cross-linking polymers and the use of their own special pre-polymer. Examples of these resin materials are MPM (Multiplex Polymer Matrix: Premium, Heraeus Kulzer, Hanau, Germany), IPN (Interpenetrating Polymer Network: Trubyte IPN, Dentsply International, New York, USA) and DCL (Double Cross Linked: SR-Postaris-DCL, Ivoclar-Vivadent, Schaan, Liechtenstein). They are the high cross-linked artificial denture teeth. Another approach to improve resin teeth, analog to the development of composite restoratives, was the addition of inorganic fillers to the polymer matrix. The composite teeth Vitapan (Vita Zahnfabrik, Bad Sackingen, Germany), SROrthosit-PE (Ivoclar-Vivadent, Schaan, Liechtenstein) and NC Veracia (Shofu, Ratingen, Germany) are the three examples of the usage of the inorganic fillers, in the form of amorphous silica, for the improvement of mechanical properties and wear resistance.

Both acrylic and porcelain teeth can be made to provide a realistic appearance. The slightly greater translucency and depth of color achieved with porcelain possibly offer this material a slight advantage in terms of esthetic. Both materials are produced into a variety of shapes, sizes, colors and shades which enable the dentist in teeth selection to suit most individuals. The difference between porcelain and polymer teeth is that polymer teeth are softer but tougher than porcelain teeth. Other differences are the low elastic modulus, high ductility and high impact strength of polymer teeth. As a result, polymer teeth are less likely to chip or fracture on impact. Furthermore, acrylic resin teeth can create chemical bonding with commonly used denture base materials. One aspect of porcelain teeth which is sometimes intolerance to the patient is the clicking noise which occurs when two porcelain teeth come into contact. The majority of artificial denture teeth used for denture construction are now toward polymer. Acceptable appearance coupled with convenient handling, greater toughness and compatibility with the acrylic denture base have made the acrylic resins more popular over the porcelain materials (22).

The artificial denture teeth are classified into two layers, enamel layer and dentin layer (18). But this description did not cover the news developed artificial denture teeth. Therefore, Loyaga-Rendon et al in 2007 introduced a new classification. The enamel layer is a clear superficial resin layer mimicking the enamel of a natural tooth. Underneath, there is a yellowish base resin layer at the ridge lap or cervical portion. In addition, the intermediate layer, a layer between the enamel and base layer, may be found in some products. Moreover, some composite resin teeth may contain two intermediate layers; the lower intermediate layer next to the base layer is an additional intermediate layer. Each layer of artificial denture teeth demonstrates different properties, such as hardness and monomer diffusion (19).

Wear mechanisms

Traditionally three terms, attrition, abrasion and erosion, have been used to describe the wear of teeth and dental materials. In the dental literature, the term erosion is used to describe surface loss attributed to chemical effects. These are usually acidic and may be the result of extrinsic causes such as dietary acids or intrinsic as a result of gastric regurgitation (23). Attrition describes surface loss at the sites of occlusal contact and abrasion is used to describe wear at non-contacting sites together with a number of other situations which cannot be ascribed to erosion or attrition. However, it has long been recognized that it is difficult to ascribe many individual cases into any one category (24). The three terms have led to some confusions because they describe clinical manifestations rather than underlying mechanisms of wear (25).

Wear can be defined as the ultimate consequence of interaction between surfaces which is manifested in gradual removal of material (26). Depending on the structure and the interaction conditions of a tribosystem, both mechanical and environmental factors influence the detachment of material. In general, it is possible to distinguish four main types of wear processes.

1. Adhesive wear

Adhesive wear occurs when surfaces slide against one another under load. The effects of friction cause the asperities on one surface to become cold welded to the other surface. Therefore there is material transfer from one surface to another (Figure 1). The volume of material transferred is proportional to the real area of contact and the sliding distance (26).

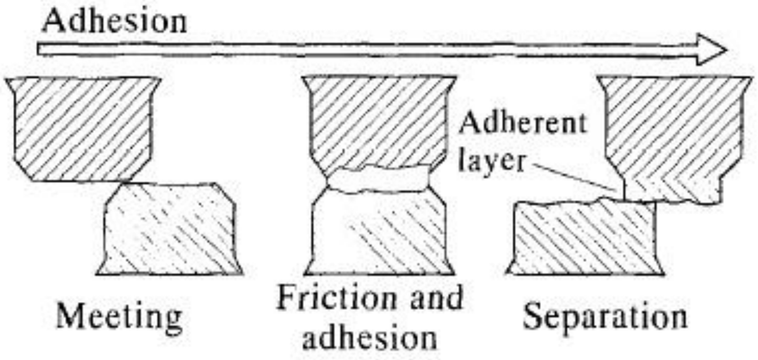


Fig. 1 Adhesive wear (26)

In the oral cavity, where saliva act as the lubricant (27), it is likely that adhesion phenomenon is limited because the object of lubrication is to reduce friction and the tendency to adhesion, and to mitigate their effects. For this reason, it has not been proven whether this type of wear contributes significantly to the wear of dental materials, but it may be suspected at locations where an opposing cusp or contact point is forced against an artificial denture tooth surface (28).

2. Abrasive wear

This is probably the most common type of wear. It occurs when hard particles plough into the softer surfaces. These particles may be an integral part of one surface (such as the filler particles protruding from a dental composite material), or they may be separate particles which are enmeshed between the surfaces. The first type of abrasion is termed two-body abrasion (Figure 2), whereas the second is termed three-body abrasion (Figure 3). If the particles are carried by a gas stream or a flowing liquid then, in engineering, this is known as erosion (26). In general, abrasive wear is proportional to the physical characteristics of the materials in contact, the geometry, shape, size and ductility of the abrasive particles, the load, and the sliding distance (29).

Although it is not the only wear mechanism in the oral cavity, abrasion probably constitutes an important consideration in the total wear process and occurs in different ways in the mouth environment, depending on the site of the materials (24). Class III and

V restorations are jeopardized predominantly by tooth brushing abrasion (30). At occlusal areas, loss of materials may be caused by both two-body and three body abrasive wears (31).

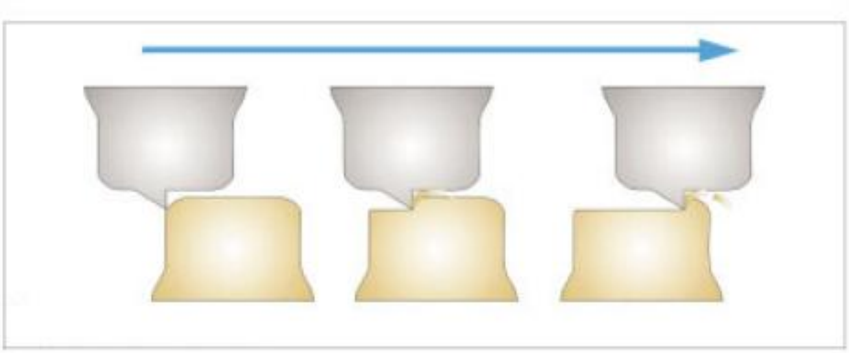


Fig. 2 Two-body abrasive wear (24)

Fig. 3 Three body abrasive wear (24)

3. Fatigue wear

When one surface slides over another, there is a zone of compression in the material ahead of the motion (Figure 4). Plastic deformation of the material causes a zone of tension behind the motion. Cracks nucleate in the subsurface and propagate as a result of repeated cycles at a depth governed by the material properties. Eventually the cracks propagate to the surface and the material that was surrounded by a network of linked cracks and hence a surface pitting or splintering can arise (26). This displaced material may itself form wear debris and cause three-body abrasion.

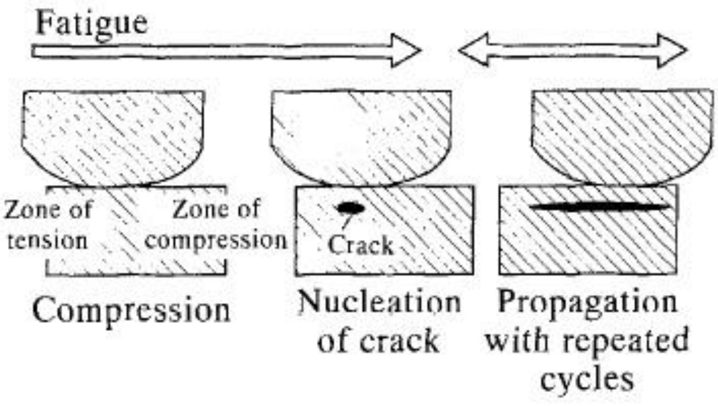


Fig. 4 Fatigue wear (26)

4. Corrosive wear

Corrosive wear results from the chemical reaction taken place between the wear surfaces and the environment. If a chemical reaction layer forms on a surface then it may be scraped away by contact with the counter surface (Figure 5). A fresh reaction layer forms on the exposed surface which is subsequently removed on the next encounter between the surfaces (32). The material which is removed results in debris which may agglomerate into the larger particles.

In the oral cavity, this type of wear can be due to chemicals from drinks, food, microorganisms, and saliva. Dental materials have undergone softening and roughening. Consequently, dental materials may show an increased abrasive wear rate (33).

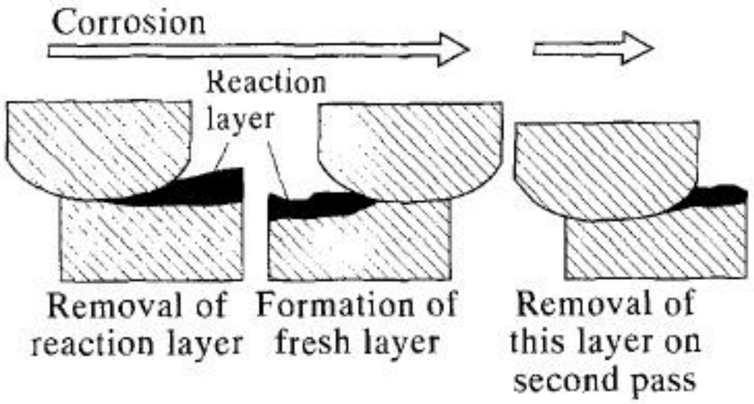


Fig. 5 Corrosive wear (26)

Wear influencing factors

1. Force

The wear testing simulator should generate clinically relevant forces, which are in range of 20-120 N (34). Studies on human beings chewing on different foods revealed that the vertical biting force in molars ranges from 20 to 120 N. When the subjects involved in the study chewed on boiled potatoes, a force of 20 N was measured, 60 N was measured when they chewed white bread or raw carrots and 100-120 N was measured when they chewed on rice crackers. The higher loading forces produce higher wear (35). The increase in wear is not linear to the increase of loading.

2. Size and shape of stylus

The pointed stylus produces more wear than a ball shaped stylus as a ball stylus has a greater contact area between stylus and tested material than a sharp one thus producing less fatigue stress on the material (36).

3. Material of stylus

There are no agreement in the literature as to which material should be used as antagonist in the wear simulation tests (17). Some of the wear simulation methods used enamel as stylus (37). However, the stylus used for these methods is prepared in difference ways. If enamel, as antagonist, is substituted with another material, both the variability and time required to fabricate the antagonists may be altered (17). Steatite, a synthetic material mainly composed of magnesium silicate, is regarded as a suitable substitute for enamel by some authors (38). The MUNICH method uses degusit, a material that consists mainly of highly condensed aluminium oxide, as stylus (37).

4. Chemical and abrasive medium

The relative wear rates depended on whether a third-party abrasive is present. The variety of foods found in the human diet may act as lubricants or as abrasives. Therefore, it is difficult to predict the effect of foods on the wear of natural and artificial denture teeth. The effects of various substances in the diet that may act as solvents and cause crazing of artificial denture teeth were not evaluated. For example, alcohol may cause a chemical breakdown of artificial denture teeth and render them more susceptible to wear

(6). The corn meal and PMMA slurry may act as a cushion that absorbed the impact stress on both surfaces. As the slurry particles were softer and more elastic than enamel or ceramics, the elastic deformation of slurry particles also absorbed some of the load applied over the specimens during the sliding contact (39). In addition, the effect of abrasive mediums (such as denture cleansers, toothpastes and environmental particles), degradation of the abrasive medium over time and pH level on wear were not examined.

Moreover, the water storage of specimens results in a slightly increase, decrease or no change of wear. However, the ranking of materials, which were tested using the Munich wear method, was not affected by water storage (40).

5. Specimen

No systematic investigations have been accomplished for the various wear test methods except for one study that investigated the influence of surface roughness on abrasive wear (41). Although the surface roughness caused by five surface treatment protocols was different between the groups, no effect on abrasive wear after 100,000 cycles has been detected.

CHAPTER III

MATERIAL AND METHODS

Specimens

Seven brands of artificial denture teeth were used in this study (Table I).

Table I Materials used in this study

Brand Name	Composition	Abbreviation	Lot No.	Manufacturer
Cosmo HXL	PMMA	CH	DW	Dentspy International, Inc., NJ, Brazil
Major Dent	PMMA	MD	7345	Major, Prodotti, Dentari, Italy
Yamahachi FX	PMMA	YF	CH0804	Yamahachi Dental Mfg.Co., Aichi Pref., Japan
Trubyte Bioform IPN	IPN	TB	17404	Dentspy International, Inc., York, PA, USA
SR Orthosit PE	UDMA, Inorganic filler	SO	009364	Ivoclar Vivadent, Naturns, Italy
Yamahachi PX	Fluro-Methacrylate, Inorganic filler	YP	CJ0124	Yamahachi Dental Mfg.Co., Aichi Pref., Japan
ACE Teeth	Porcelain	AT	060802	Shofu, Kyoto, Japan

Preparation of the specimens

A set of 8 upper posterior teeth including both premolars and molars of each brand was sectioned to make 56 specimens. Each tooth was sectioned 2 times bucco-lingually perpendicular to its mesio-distal midline by a low speed cutting machine (Isomet 1000, Buehler, Lake Bluff, IL, USA). The first section line was along the midline, the second section were 2.3±0.1 mm from the initial section.

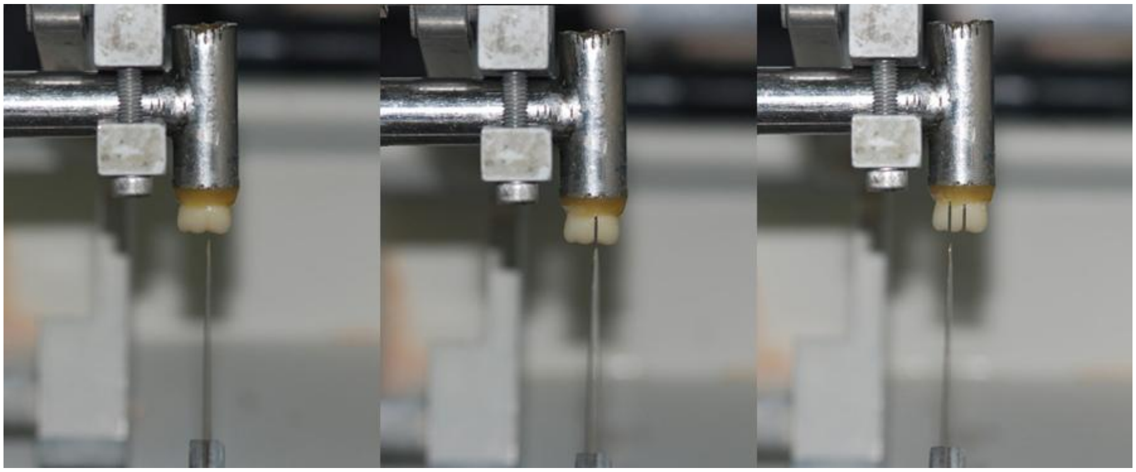


Fig. 6 Artificial denture tooth sectioning

Fig. 7 Section of artificial denture tooth

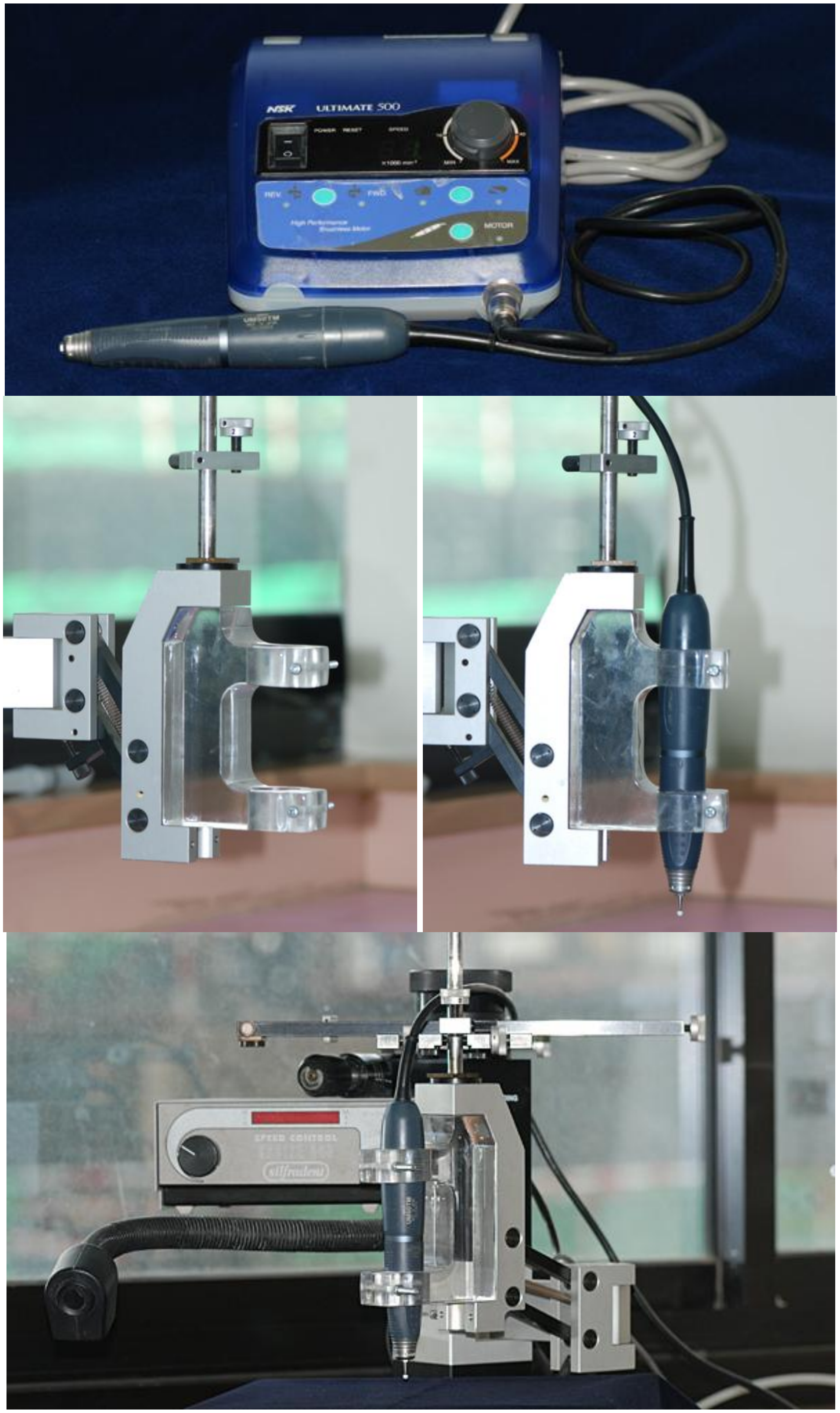


Fig. 8 Setting of wear simulating apparatus

The middle slices were used, the outer portions were excluded. The slabs were polished with silicon carbide abrasive paper No. 600, 800, 1,000, and 1,200 and finally polished using 0.5 µm alumina oxides slurry (Leco Corp, St. Joseph, MI, USA). The final thickness of each specimen was 2.0±0.1 mm. The specimens were stored in desiccators for 48 hours before testing.

Wear testing

The in vitro two-body wear testing apparatus was used in this study (Figure 8). The wear testing was set up following a pin on disc design. A ceramic (aluminum oxide: Dura-White® Stones, RD-1, Shofu, Kyoto, Japan) (diameter 3 mm) (Ra 2.28 µm) (Hardness 15 GPa) (Elastic modulus 99 GPa) was used as the antagonist material (Figure 9). The antagonist was vertically loaded with 15 N at 1,000 rpm for 10,000 cycles on the sub-enamel layer (base layer of MD, CH, YF, TB, YP, and AT; and intermediate layer of SO) of the specimen’s surface without lateral movement. No chemical or abrasive medium were used during wear testing. All wear tests were performed at room temperature (25±2°C) and distilled water was continuously flushed over specimens during testing. After the wear test, the specimens were removed from the apparatus, and the surfaces were cleaned with distilled water before measurements.

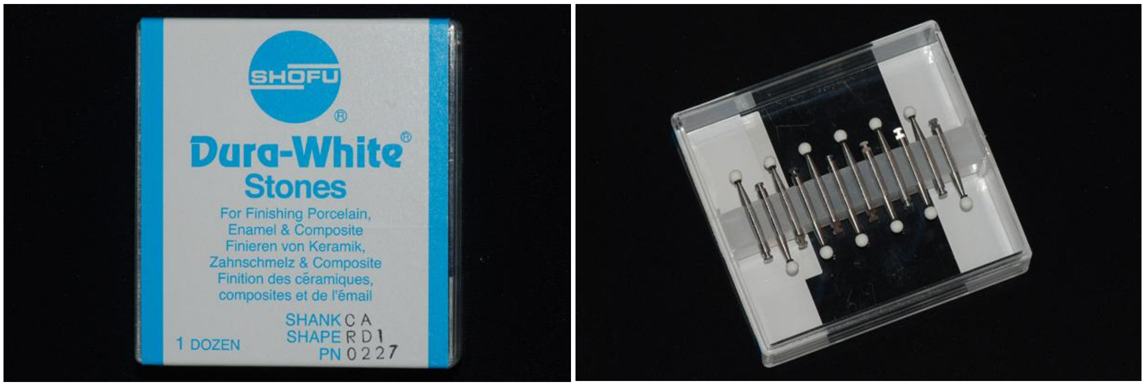


Fig. 9 Aluminium oxide antagonists

Measurement of volume loss and weight loss

Before and after the wear test, the weight (mg) of each specimen was measured on an electric balance (0.0001 g accuracy) (SPB31, Scaltec, Göttingen, Germany) (Figure 10) after placing the specimen in a desiccator for 48 hours. Weight loss of each specimen was calculated by difference of weights before and after wear testing. Mean weights were calculated by averaging three readings on each specimen. After the wear test, volume loss (mm^3) of each specimen was measured by a profilometer (TalyScan 150, Taylor Hobson Ltd., Leicester, United Kingdom) (Figure 11). A contact stylus gauge was used to analyze wear facets. The instrument scans at a speed 3,000 µm/s with a reading interval of 5 µm. The amount of volume loss was calculated from a depth of wear surface using TalyScan 150 software (Taylor Hobson Ltd., Leicester, United Kingdom) (Figure 12).

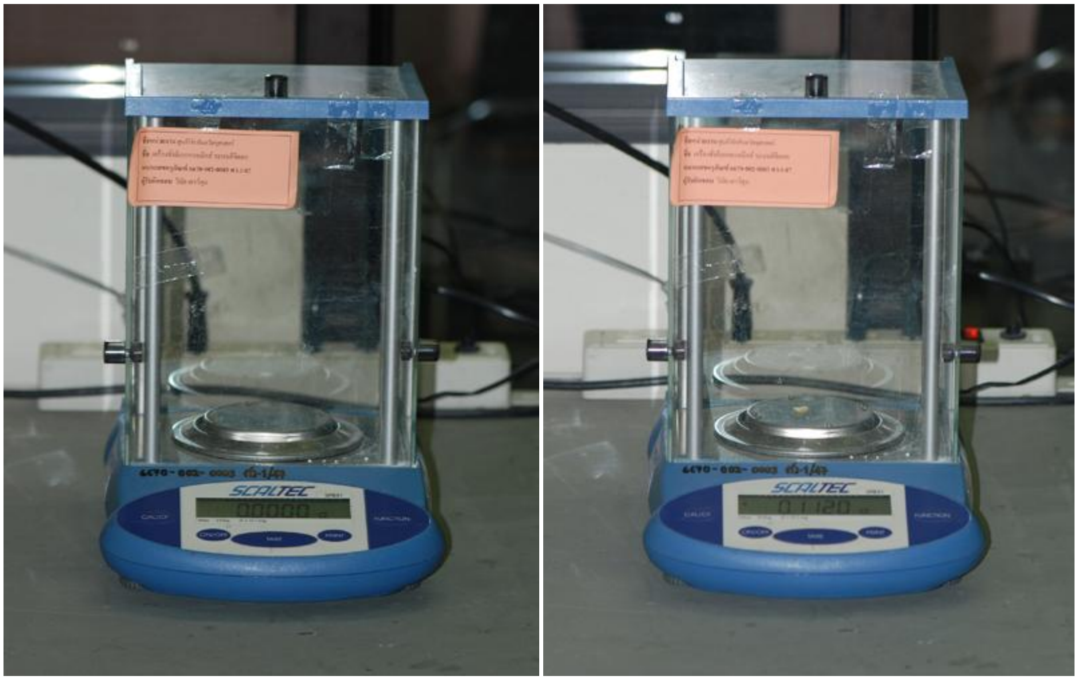
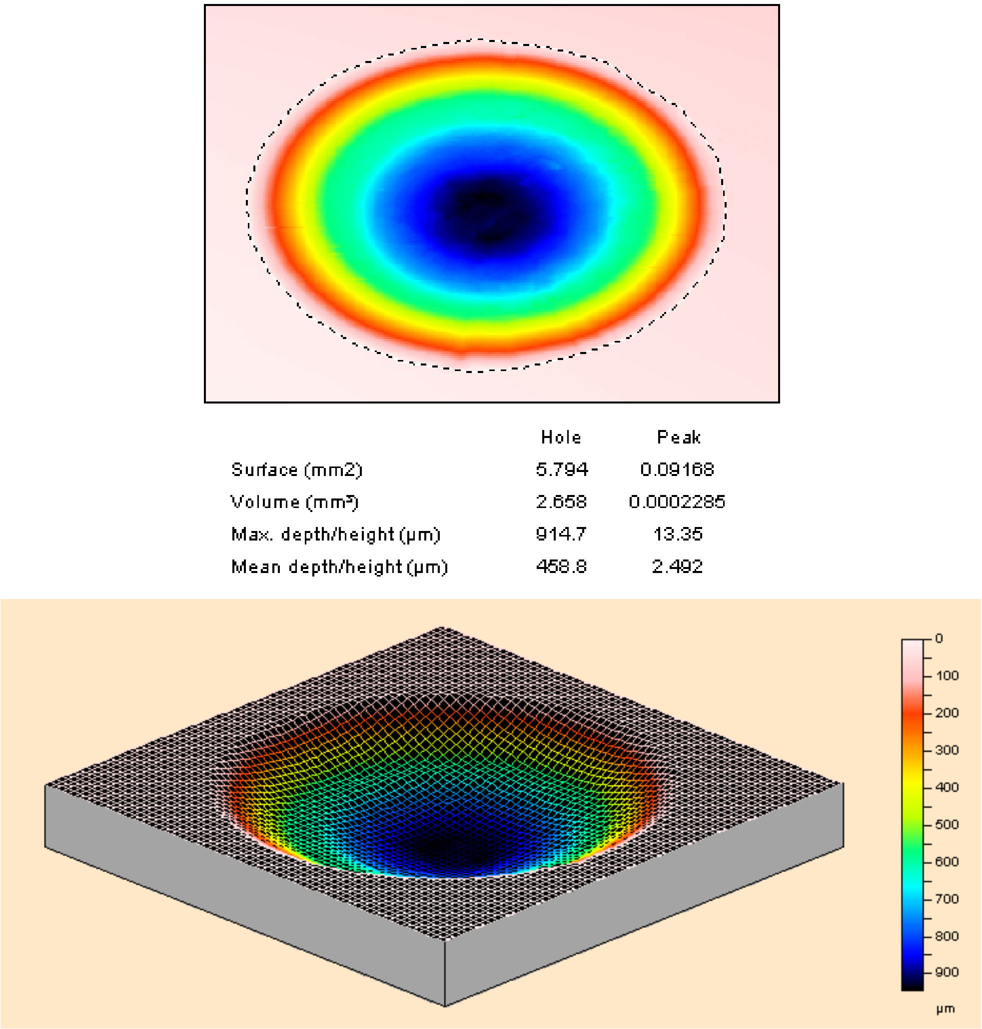


Fig. 10 Weight measurement

Fig. 11 Profilometer



	Hole	Peak
Surface (mm2)	5.794	0.09168
Volume (mm³)	2.658	0.0002285
Max. depth/height (µm)	914.7	13.35
Mean depth/height (µm)	458.8	2.492

Fig. 12 Volume loss analysis

Statistical analysis

Data were analyzed by using statistical analysis software (SPSS 16.0, SPSS Inc, Chicago, IL, USA). Data were individually analyzed using one-way analysis of variance (ANOVA) (α=0.05) and the Tamhane’s T2 test was used for post hoc analysis (α=0.05). This was because the equality of variances could not be assumed. The generalized linear models between weight loss and volume loss were also analyzed.

CHAPTER IV

RESULTS

The mean of volume loss, and weight loss of 7 artificial denture teeth were summarized in Table II.

Table II Volume loss and weight loss of artificial denture teeth

Brand Name	Volume loss (mm^3)	Weight loss (mg)
Cosmo HXL	0.210 (0.078) ^{a}	0.8 (0.3) ^{a}
Major Dent	0.071 (0.043) ^{b}	0.2 (0.1) ^{b}
Yamahachi FX	0.054 (0.016) ^{b}	0.2 (0.1) ^{b}
Trubyte Bioform IPN	0.693 (0.197) ^{c}	1.4 (0.2) ^{c}
SR Orthosit PE	0.040 (0.009) ^{b}	0.3 (0.1) ^{a,b}
Yamahachi PX	0.056 (0.019) ^{b}	0.3 (0.1) ^{a,b}
ACE Teeth	0.054 (0.008) ^{b}	0.2 (0.2) ^{b}

Average values with standard deviations in parentheses.
Different in superscript letters indicate statistical differences ($p<0.05$).

High cross-linked teeth (TB) had the greatest volume loss (0.693 mm^3) ($p<0.01$). CH had greater volume loss (0.210 mm^3) than other artificial denture teeth ($p<0.05$). The volume loss of composite resin teeth (SO, and YP), porcelain teeth (AT), and the other two conventional acrylic resin teeth (MD, and YF) were not significantly different ($p>0.05$) (Figure 13).

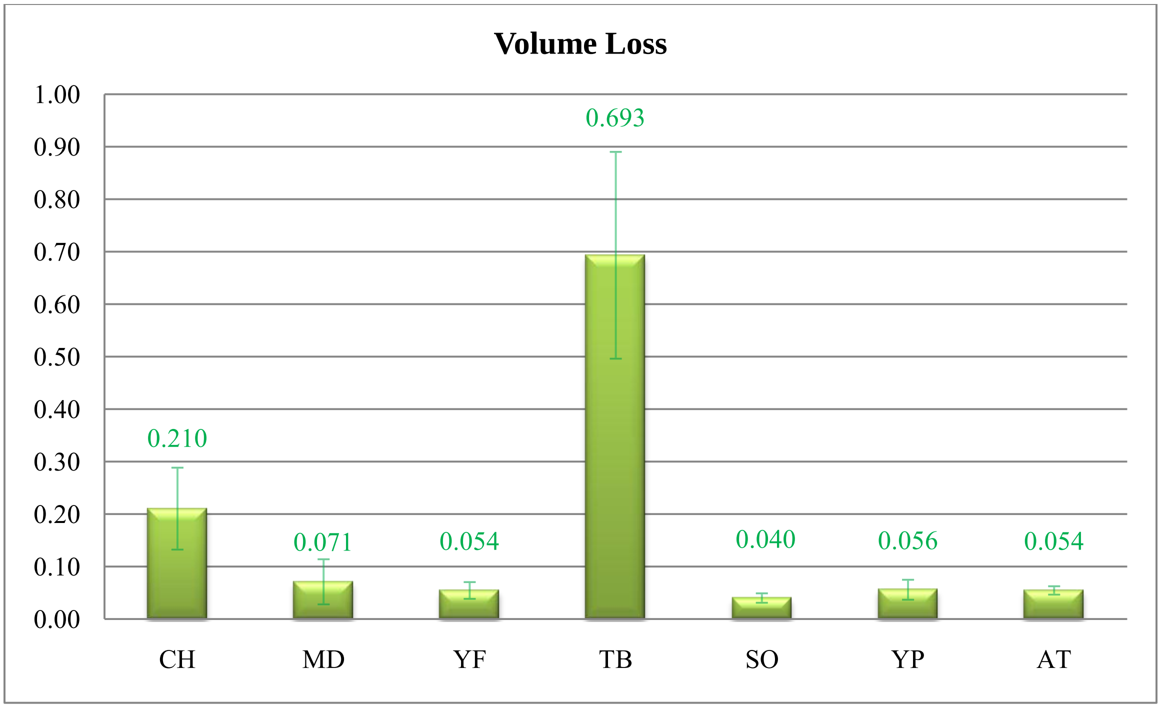


Fig. 13 Volume loss of artificial denture teeth

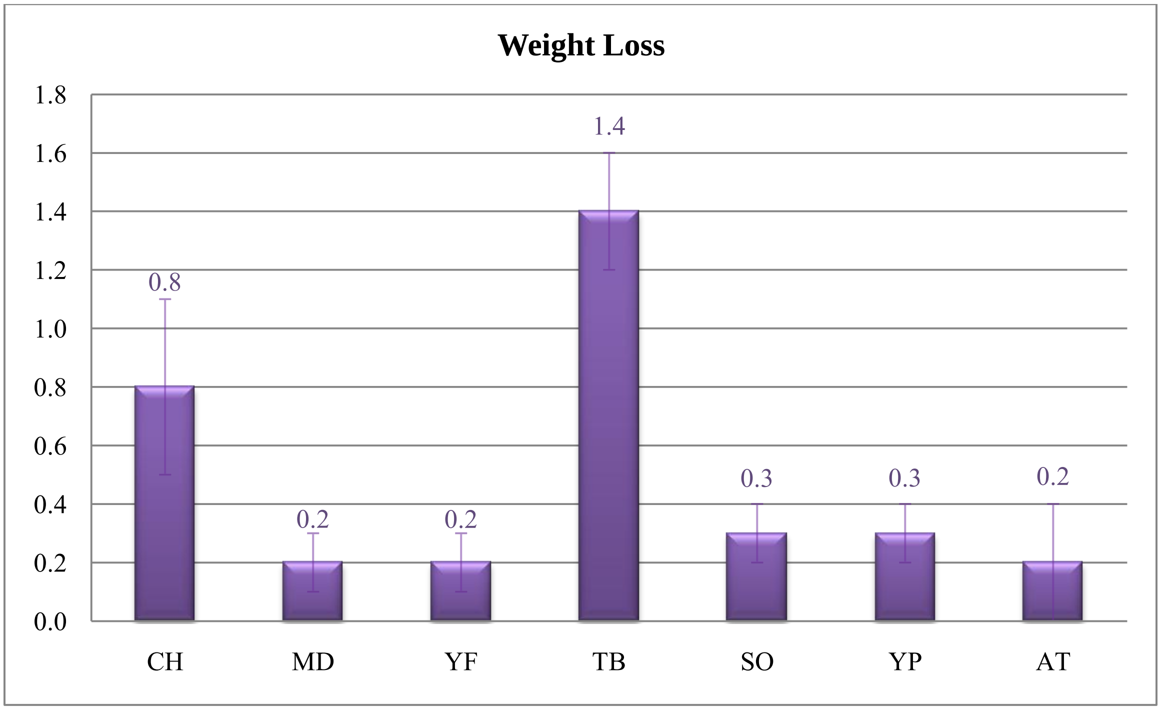


Fig. 14 Weight loss of artificial denture teeth

The weight loss demonstrated a similar trend as volume loss (Figure 14). High cross-linked teeth (TB) exhibited the greatest weight loss (1.4 mg) ($p<0.01$). CH exhibited greater weight loss than other conventional acrylic resin teeth (MD, and YF) and porcelain teeth (AT) ($p<0.05$) but not significant greater than composite resin teeth (SO, and YP) ($p>0.05$).

A significant positive linear correlation between volume loss and weight loss was observed ($R^2=0.8165$, $p<0.01$) (Figure 15).

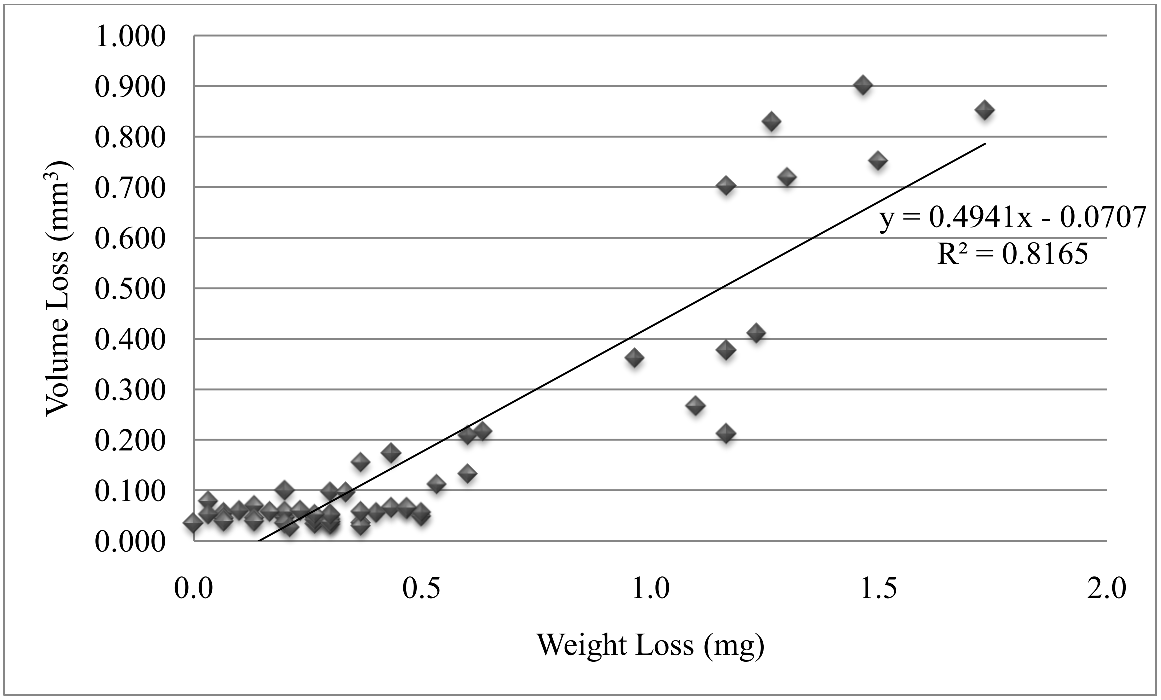


Fig. 15 Relationship between weight loss and volume loss

CHAPTER V

DISCUSSION

In this study, in vitro testing was used to evaluate wear resistance of artificial denture teeth. Clinical studies have considerable limitations such as complex methodologies, financial expenditures, time consuming, and difficulties in measurement and analysis (42). Laboratory studies have been widely used to determine the wear resistance of a material. While intraoral wear mechanisms are so complicated that in vitro studies cannot simulate all their conditions (42). They still play a key role in understanding the wear mechanism and are the majority of evaluation methods of the clinical wear resistance of dental materials.

The two-body wear testing device used in this study was modified from isoparallelometer and micromoter, to simulate a direct contact between the test specimens and antagonists. The aluminium oxide antagonist was used in this study. Aluminium oxide is one of many common enamel substituted antagonists (17). Because natural tooth has many variations such as size, shape and composition, this substituted material is selected in order to reduce variations and time required to fabricate the antagonists (17). This study was mainly focused on material composition and wear resistance without abrasive medium. This is because it is difficult to predict the effect of abrasive medium on wear behavior. Some in vitro studies have reported conflicting results with increasing wear with abrasive slurry, hard abrasive particles (43), or reducing wear with lubrication (34). The standardization and specification of artificial denture tooth sample in some previous studies were not exactly focused. Those test areas were unidentified (7) and no standardized sample preparation (9, 11, 12). Moreover, most studies did not describe location and tested layer. With the limitation of enamel layer thickness, the vertical wear facet probably penetrated into the sub-enamel layer. This could affect the overall wear resistance. In this study, the orientation of test area was controlled to be within sub-enamel layer.

The results of this study support the hypothesis that wear, including weight loss and volume loss was affected by composition of artificial denture teeth. In the present study, high cross-linked acrylic resin teeth demonstrated the lowest wear resistance in both weight loss and volume loss. Volume loss of one conventional acrylic resin teeth (CH) was higher than the others but lower than high cross-linked acrylic resin teeth. However, the results showed no significant difference in wear resistance among composite resin, porcelain, and conventional acrylic resin teeth; except for CH. The result of this present study was not in line with some previous studies which showed a greater wear resistance of composite resin teeth than conventional or high cross-linked acrylic resin teeth (7-11, 13, 44), but supported the studies which demonstrated the less wear resistance of composite resin teeth (14, 16, 45).

In this study, high cross-linked acrylic resin teeth (TB) showed the worst wear behaviors both in weight loss and volume loss. This result was partially in line with a previous study of which the great volume loss was found in high cross-linked acrylic resin teeth (12, 14). This finding may be attributed by two reasons: degree of cross linking and product composition. Although cross-linking produces dimensional stability and improves toughness, high levels of cross-linking lead to brittleness and a loss of toughness (46). Therefore high cross-linked acrylic resin may be easily abraded during this abrasive wear testing. Secondly, the material is a homo-interpenetrating polymer network (IPN) of polymethyl methacrylate (47). A homo-IPN is an IPN where both network polymers are based on the same monomer. Polymer network I is suspension polymerized and dispersed in monomer II plus cross-linker and activator. Some of the monomer II in the mixture swells into the suspension particles. The mixture monomer II is then polymerized to make a sequential homo-IPN. Two advantages for the IPN over a conventional linear PMMA are the reduction in swelling by solvents in oral environment and to be ground easily because the product is removed as a fine powder, while a linear material tends to burn during grinding. As the antagonist interacts with test material, a transfer layer or transfer film commonly occurs on the superficial layer of the material. The adhesive strength of the transfer layer to the antagonist surface has a strong influence on the wear rate (46). The amount of transfer layer of TB might be little and also lack of adhesion because it was produced as a fine powder which was easy to remove rather than a burnt layer. This may be why TB showed the least wear resistance. Similarly, CH, which manufacturer indicated ten percentage of a cross-linking agent that was hypothesized to be less than TB; a claimed highly cross-linked denture teeth, was the second least in wear resistance.

Although the two composite resin teeth tested in this study (SO and YP) were not significant different in wear resistance from both volume and weight loss. Volume loss of SO was slightly insignificant lower than YP. According to the manufacturer's data, the tested layer of SO was the intermediate composite resin layer but in YP, it was the base layer which is conventional acrylic resin. Both SO and YP have enamel and intermediate layers. However, these layers in YP are much thinner (1.55±0.31 mm), so it was quite difficult to confine the antagonist within this intermediate layer. Therefore, the testing area of YP was at the base layer, whereas it was at the intermediate layer in SO. Volume loss of SO was the lowest, dissimilar to weight loss. The reason might be the higher density of the filler or other components of composite resin compared with those of conventional acrylic resin layers.

The average wear resistance of porcelain teeth (AT) in the present study was not as high as in a previous study (15). The results of this study demonstrated that porcelain was more sensitive to tensile stress than to compressive stress. The present study used two-body wear testing, which produces mainly abrasive wear. The conditions in this study were continuous rotation without vertical movement and no lubricant slurry particles. Water circulation cannot sufficiently reduce heat or stress between surfaces. These conditions might have produced a high coefficient of friction between the surfaces, thus the wear resistance of porcelain was decreased (48). Subsurface cracks have been found when using high sliding cycles (49). Furthermore, brittle cracks and delamination are often observed in feldsphatic porcelain, especially under non-lubricated friction. These incidents are correlated to the fatigue wear mechanism, described by Mair et al. (26) where the zone of compression occurs in porcelain ahead of the motion, when one material slides over another. The plastic deformation property of the porcelain causes a zone of tension behind the motion. Repeated cycles cause cracks to initiate in the subsurface of the porcelain and propagate. The cracks ultimately propagate to the surface and the porcelain surrounded by cracks is lost.

A positive relationship between weight loss and volume loss was observed in this study. Hence, it may appear reasonable to use only the easier variable like weight loss in the evaluation. However, there are many factors which make weight loss a poor indicator compared to volume loss. With equal weight, the difference in densities of each composition in artificial denture teeth such as ceramic glass, filler or other resin based matrix, has an influence on weight. Besides, water absorption and evaporation, especially in resin based material, certainly affect the weight of the material (50). As a result, the precision of the gravimetric method is limited, and some errors can occur.

Wear evaluation is theoretically difficult, because wear depends on a number of parameters other than the mechanical and physical properties of the material. These parameters include temperature, sliding speed, normal pressure, counterface roughness, and transfer film (46). The wear resistance of the artificial denture teeth may be influenced by many factors. The multifactorial nature of the development of wear in artificial denture teeth during function makes the exact influence of each parameter on wear difficult to dissect (46).

In selecting artificial denture teeth, type and composition are not the only consideration. Special consideration should be placed upon sub-enamel layer properties as well. Occlusal adjustment prior to, and after, denture delivery will inevitably expose this layer into occlusion with the opposing dentition; natural or artificial. When the artificial denture teeth are selected properly, the serving time of the denture will be longer. Therefore, wear resistance of sub-enamel layer is the important information in choosing the artificial denture teeth.

CHAPTER VI

CONCLUSIONS

Within the limitations of this in vitro study, it can be concluded as following:

1. Wear resistance varied among the denture tooth materials. Volume loss of Trubyte Bioform IPN was the highest ($p<0.01$), followed by Cosmo HXL ($p<0.05$).
2. Weight loss of Trubyte Bioform IPN was the highest ($p<0.01$).
3. A significant positive linear correlation between volume loss and weight loss was observed ($R^2=0.9178$, $p<0.01$).

REFERENCES

(1) Schultz, A. W. Comfort and chewing efficiency in dentures. J Prosthet Dent. 1 (1951): 38-48.

(2) Ekfeldt, A.; and Karlsson, S. Changes of masticatory movement characteristics after prosthodontic rehabilitation of individuals with extensive tooth wear. Int J Prosthodont. 9 (1996): 539-546.

(3) Bani, D.; Bani, T.; and Bergamini, M. Morphologic and biochemical changes of the masseter muscles induced by occlusal wear: studies in a rat model. J Dent Res. 78 (1999): 1735-1744.

(4) Powers, J. M.; and Sakaguchi, R. L. Craig's Restorative Dental Materials, pp. 151,544-545. St Louis: Mosby Inc, 2006.

(5) Phunthikaphadr, T.; Takahashi, H.; and Arksornnukit, M. Pressure transmission and distribution under impact load using artificial denture teeth made of different materials. J Prosthet Dent. 102 (2009): 319-327.

(6) Coffey, J. P.; Goodkind, R. J.; DeLong, R., et al. In vitro study of the wear characteristics of natural and artificial teeth. J Prosthet Dent. 54 (1985): 273-280.

(7) Whitman, D. J.; McKinney, J. E.; Hinman, R. W., et al. In vitro wear rates of three types of commercial denture tooth materials. J Prosthet Dent. 57 (1987): 243-246.

(8) Abe, Y.; Sato, Y.; Akagawa, Y., et al. An in vitro study of high-strength resin posterior denture tooth wear. Int J Prosthodont. 10 (1997): 28-34.

(9) Hirano, S.; May, K. B.; Wagner, W. C., et al. In vitro wear of resin denture teeth. J Prosthet Dent. 79 (1998): 152-155.

(10) Suzuki, S.; and Tamura, F. In Vitro Wear of Nano-Composite Denture Teeth. J Dent Res. 81 (2002): A-170.

(11) Suzuki, S. In vitro wear of nano-composite denture teeth. J Prosthodont. 13 (2004): 238-243.

(12) Stober, T.; Lutz, T.; Gilde, H., et al. Wear of resin denture teeth by two-body contact. Dent Mater. 22 (2006): 243-249.

(13) Ghazal, M.; Hedderich, J.; and Kern, M. Wear of feldspathic ceramic, nano-filled composite resin and acrylic resin artificial teeth when opposed to different antagonists. Eur J Oral Sci. 116 (2008): 585-592.

(14) Winkler, S.; Monasky, G. E.; and Kwok, J. Laboratory wear investigation of resin posterior denture teeth. J Prosthet Dent. 67 (1992): 812-814.

(15) Ghazal, M.; Yang, B.; Ludwig, K., et al. Two-body wear of resin and ceramic denture teeth in comparison to human enamel. Dent Mater. 24 (2008): 502-507.

(16) Ghazal, M.; Steiner, M.; and Kern, M. Wear resistance of artificial denture teeth. Int J Prosthodont. 21 (2008): 166-168.

(17) Heintze, S. D. How to qualify and validate wear simulation devices and methods. Dent Mater. 22 (2006): 712-734.

(18) Raptis, C. N.; Powers, J. M.; and Fan, P. L. Frictional behavior and surface failure of acrylic denture teeth. J Dent Res. 60 (1981): 908-913.

(19) Loyaga-Rendon, P. G.; Takahashi, H.; Hayakawa, I., et al. Compositional characteristics and hardness of acrylic and composite resin artificial teeth. J Prosthet Dent. 98 (2007): 141-149.

(20) Woelfel, J. B.; Paffenbarger, G. C.; and Sweeney, W. T. Dimensional changes occurring in dentures during processing. J Am Dent Assoc. 61 (1960): 413-430.

(21) Anusavice, K. J. Phillips' Science of Dental Materials, pp. 711,754-755: W B Saunders Co, 2006.

(22) McCabe, J. F.; and Walls, A. Applied dental materials, pp. 133-135: Blackwell Scientific Publications, 2008.

(23) Jarvinen, V. K.; Rytomaa, II; and Heinonen, O. P. Risk factors in dental erosion. J Dent Res. 70 (1991): 942-947.

(24) Turssi, C. P.; De Moraes Purquerio, B.; and Serra, M. C. Wear of dental resin composites: insights into underlying processes and assessment methods--a review. J Biomed Mater Res B Appl Biomater. 65 (2003): 280-285.

(25) Mair, L. H. Wear in dentistry--current terminology. J Dent. 20 (1992): 140-144.

(26) Mair, L. H.; Stolarski, T. A.; Vowles, R. W., et al. Wear: mechanisms, manifestations and measurement. Report of a workshop. J Dent. 24 (1996): 141-148.

(27) Yap, A. U.; Teoh, S. H.; Hastings, G. W., et al. Comparative wear ranking of dental restorative materials utilizing different wear simulation modes. J Oral Rehabil. 24 (1997): 574-580.

(28) Soderholm, K. J.; and Richards, N. D. Wear resistance of composites: a solved problem? Gen Dent. 46 (1998): 256-263; quiz 264-255.

(29) Abebe, M.; and Appl, F. C. Theoretical analysis of the basic mechanics of the abrasive processes. Part 1: General model. Wear. 126 (1988): 251-266.

(30) Asmussen, E. Clinical relevance of physical, chemical, and bonding properties of composite resins. Oper Dent. 10 (1985): 61-73.

(31) Mair, L. H. Measurement and analysis of clinical abrasion--a modified approach. Dent Mater. 6 (1990): 271-275.

(32) Sulong, M. Z.; and Aziz, R. A. Wear of materials used in dentistry: a review of the literature. J Prosthet Dent. 63 (1990): 342-349.

(33) Wu, W.; and McKinney, J. E. Influence of chemicals on wear of dental composites. J Dent Res. 61 (1982): 1180-1183.

(34) Schindler, H. J.; Stengel, E.; and Spiess, W. E. Feedback control during mastication of solid food textures--a clinical-experimental study. J Prosthet Dent. 80 (1998): 330-336.

(35) Lutz, F.; Krejci, I.; and Barbakow, F. Chewing pressure vs. wear of composites and opposing enamel cusps. J Dent Res. 71 (1992): 1525-1529.

(36) Krejci, I.; Lutz, F.; and Zedler, C. Effect of contact area size on enamel and composite wear. J Dent Res. 71 (1992): 1413-1416.

(37) Krejci, I.; Albert, P.; and Lutz, F. The influence of antagonist standardization on wear. J Dent Res. 78 (1999): 713-719.

(38) Wassell, R. W.; McCabe, J. F.; and Walls, A. W. Wear characteristics in a two-body wear test. Dent Mater. 10 (1994): 269-274.

(39) Kadokawa, A.; Suzuki, S.; and Tanaka, T. Wear evaluation of porcelain opposing gold, composite resin, and enamel. J Prosthet Dent. 96 (2006): 258-265.

(40) Sarrett, D. C.; Soderholm, K. J.; and Batich, C. D. Water and abrasive effects on three-body wear of composites. J Dent Res. 70 (1991): 1074-1081.

(41) Turssi, C. P.; Ferracane, J. L.; and Serra, M. C. Abrasive wear of resin composites as related to finishing and polishing procedures. Dent Mater. 21 (2005): 641-648.

(42) Yip, K. H.; Smales, R. J.; and Kaidonis, J. A. Differential wear of teeth and restorative materials: clinical implications. Int J Prosthodont. 17 (2004): 350-356.

(43) Ramalho, A. M.; and Antunes, V. R. Reciprocating wear test of dental composites: effect on the antagonist. Wear. 259 (2005): 1005-1011.

(44) von Fraunhofer, J. A.; Razavi, R.; and Khan, Z. Wear characteristics of high-strength denture teeth. J Prosthet Dent. 59 (1988): 173-175.

(45) Abe, Y.; Sato, Y.; Taji, T., et al. An in vitro wear study of posterior denture tooth materials on human enamel. J Oral Rehabil. 28 (2001): 407-412.

(46) Lampman, S. Characterization and Failure Analysis of Plastics, pp. 8-9,17,267-268,272-273. OH: ASM International, Materials Park, 2003.

(47) Klempner, D.; Sperling, L. H.; and Utracki, L. A. Interpenetrating Polymer Networks, pp. 31-32. Washington DC: American Chemical Society, 1994.

(48) Schuh, C.; Kinast, E. J.; Mezzomo, E., et al. Effect of glazed and polished surface finishes on the friction coefficient of two low-fusing ceramics. J Prosthet Dent. 93 (2005): 245-252.

(49) Yu, H. Y.; Cai, Z. B.; Ren, P. D., et al. Friction and wear behavior of dental feldspathic porcelain. Wear. 261 (2006): 611-621.

(50) Ekfeldt, A.; and Oilo, G. Occlusal contact wear of prosthodontic materials. An in vivo study. Acta Odontol Scand. 46 (1988): 159-169.

APPENDIX

APPENDIX

Contents **Page**

Statistical analysis

STATISTIC ANALYSIS OF VOLUME LOSS

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Type of Tooth	Statistic	df	Sig.	Statistic	df	Sig.
Volume Loss (mm^3)	Cosmo HXL	.221	8	.200*	.937	8	.583
	Major Dent	.263	8	.109	.837	8	.071
	Yamahachi FX	.130	8	.200*	.964	8	.844
	Bioform IPN	.270	8	.089	.853	8	.103
	SR Orthosit PE	.125	8	.200*	.970	8	.901
	Yamahachi PX	.232	8	.200*	.841	8	.077
	ACE Teeth	.192	8	.200*	.932	8	.530

a. Lilliefors Significance Correction

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

Descriptives

Volume Loss

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Cosmo HXL	8	.21011	.078545	.027770	.14445	.27578	.111	.361
Major Dent	8	.07070	.042728	.015107	.03498	.10642	.034	.155
Yamahachi FX	8	.05419	.016221	.005735	.04063	.06775	.032	.078
Bioform IPN	8	.69286	.196562	.069495	.52853	.85719	.377	.901
SR Orthosit PE	8	.03974	.009214	.003258	.03204	.04744	.026	.052
Yamahachi PX	8	.05555	.018559	.006562	.04003	.07106	.038	.095
ACE Teeth	8	.05437	.008024	.002837	.04766	.06108	.038	.065
Total	56	.16822	.236073	.031547	.10500	.23144	.026	.901

Test of Homogeneity of Variances

Volume Loss (mm^3)

Levene Statistic	df1	df2	Sig.
8.864	6	49	.000

ANOVA

Volume Loss (mm^3)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2.733	6	.456	67.295	.000
Within Groups	.332	49	.007		
Total	3.065	55			

Post Hoc

Multiple Comparisons

Volume Loss (mm^3)
Tamhane

					95% Confidence Interval	
(I) Type of Tooth	(J) Type of Tooth	Mean Difference (I-J)	Std. Error	Sig.	Lower Bound	Upper Bound
Cosmo HXL	Major Dent	.139412*	.031613	.023	.01524	.26359
	Yamahachi FX	.155919*	.028356	.014	.02982	.28202
	Bioform IPN	-.482750*	.074838	.002	-.79211	-.17339
	SR Orthosit PE	.170371*	.027960	.009	.04296	.29778
	Yamahachi PX	.154565*	.028535	.015	.02895	.28018
	ACE Teeth	.155744*	.027914	.016	.02816	.28333
Major Dent	Cosmo HXL	-.139412*	.031613	.023	-.26359	-.01524
	Yamahachi FX	.016506	.016159	1.000	-.05081	.08382
	Bioform IPN	-.622163*	.071118	.001	-.93730	-.30703
	SR Orthosit PE	.030959	.015454	.833	-.03756	.09948
	Yamahachi PX	.015152	.016470	1.000	-.05203	.08234
	ACE Teeth	.016331	.015371	1.000	-.05243	.08509

Yamahachi FX	Cosmo HXL	-.155919*	.028356	.014	-.28202	-.02982
	Major Dent	-.016506	.016159	1.000	-.08382	.05081
	Bioform IPN	-.638669*	.069731	.001	-.95845	-.31889
	SR Orthosit PE	.014453	.006596	.664	-.01127	.04017
	Yamahachi PX	-.001354	.008715	1.000	-.03361	.03090
	ACE Teeth	-.000175	.006398	1.000	-.02571	.02536
Bioform IPN	Cosmo HXL	.482750*	.074838	.002	.17339	.79211
	Major Dent	.622163*	.071118	.001	.30703	.93730
	Yamahachi FX	.638669*	.069731	.001	.31889	.95845
	SR Orthosit PE	.653121*	.069571	.001	.33270	.97355
	Yamahachi PX	.637315*	.069804	.001	.31782	.95681
	ACE Teeth	.638494*	.069553	.001	.31799	.95900
SR Orthosit PE	Cosmo HXL	-.170371*	.027960	.009	-.29778	-.04296
	Major Dent	-.030959	.015454	.833	-.09948	.03756
	Yamahachi FX	-.014453	.006596	.664	-.04017	.01127
	Bioform IPN	-.653121*	.069571	.001	-.97355	-.33270
	Yamahachi PX	-.015806	.007326	.700	-.04503	.01342
	ACE Teeth	-.014627	.004320	.091	-.03062	.00136
Yamahachi PX	Cosmo HXL	-.154565*	.028535	.015	-.28018	-.02895
	Major Dent	-.015152	.016470	1.000	-.08234	.05203
	Yamahachi FX	.001354	.008715	1.000	-.03090	.03361
	Bioform IPN	-.637315*	.069804	.001	-.95681	-.31782
	SR Orthosit PE	.015806	.007326	.700	-.01342	.04503
	ACE Teeth	.001179	.007149	1.000	-.02800	.03036
ACE Teeth	Cosmo HXL	-.155744*	.027914	.016	-.28333	-.02816
	Major Dent	-.016331	.015371	1.000	-.08509	.05243
	Yamahachi FX	.000175	.006398	1.000	-.02536	.02571
	Bioform IPN	-.638494*	.069553	.001	-.95900	-.31799
	SR Orthosit PE	.014627	.004320	.091	-.00136	.03062
	Yamahachi PX	-.001179	.007149	1.000	-.03036	.02800

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

STATISTIC ANALYSIS OF WEIGHT LOSS

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Type of Tooth	Statistic	df	Sig.	Statistic	df	Sig.
Weight Loss (g)	Cosmo HXL	.315	8	.059	.865	8	.133
	Major Dent	.152	8	.200*	.965	8	.857
	Yamahachi FX	.152	8	.200*	.965	8	.857
	Bioform IPN	.257	8	.127	.848	8	.091
	SR Orthosit PE	.284	8	.057	.906	8	.324
	Yamahachi PX	.226	8	.200*	.899	8	.283
	ACE Teeth	.162	8	.200*	.952	8	.731

a. Lilliefors Significance Correction

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

Descriptives

Weight Loss (g)

					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
Cosmo HXL	8	.750	.3024	.1069	.497	1.003	.4	1.2
Major Dent	8	.200	.1309	.0463	.091	.309	.0	.4
Yamahachi FX	8	.200	.1309	.0463	.091	.309	.0	.4
Bioform IPN	8	1.362	.1847	.0653	1.208	1.517	1.2	1.7
SR Orthosit PE	8	.337	.0916	.0324	.261	.414	.2	.5
Yamahachi PX	8	.350	.1309	.0463	.241	.459	.1	.5
ACE Teeth	8	.213	.1553	.0549	.083	.342	.0	.5
Total	56	.487	.4349	.0581	.371	.604	.0	1.7

Test of Homogeneity of Variances

Weight Loss (g)

Levene Statistic	df1	df2	Sig.
4.695	6	49	.001

ANOVA

Weight Loss (g)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.935	6	1.489	49.766	.000
Within Groups	1.466	49	.030		
Total	10.401	55			

Post Hoc

Multiple Comparisons

Weight Loss (g)
Tamhane

(I) Type of Tooth	(J) Type of Tooth	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Cosmo HXL	Major Dent	.5500*	.1165	.019	.075	1.025
	Yamahachi FX	.5500*	.1165	.019	.075	1.025
	Bioform IPN	-.6125*	.1253	.009	-1.095	-.130
	SR Orthosit PE	.4125	.1117	.114	-.067	.892
	Yamahachi PX	.4000	.1165	.135	-.075	.875
	ACE Teeth	.5375*	.1202	.022	.061	1.014
Major Dent	Cosmo HXL	-.5500*	.1165	.019	-1.025	-.075
	Yamahachi FX	.0000	.0655	1.000	-.241	.241
	Bioform IPN	-1.1625*	.0800	.000	-1.465	-.860
	SR Orthosit PE	-.1375	.0565	.481	-.351	.076
	Yamahachi PX	-.1500	.0655	.556	-.391	.091
	ACE Teeth	-.0125	.0718	1.000	-.279	.254

Yamahachi FX	Cosmo HXL	-.5500*	.1165	.019	-1.025	-.075
	Major Dent	.0000	.0655	1.000	-.241	.241
	Bioform IPN	-1.1625*	.0800	.000	-1.465	-.860
	SR Orthosit PE	-.1375	.0565	.481	-.351	.076
	Yamahachi PX	-.1500	.0655	.556	-.391	.091
	ACE Teeth	-.0125	.0718	1.000	-.279	.254
Bioform IPN	Cosmo HXL	.6125*	.1253	.009	.130	1.095
	Major Dent	1.1625*	.0800	.000	.860	1.465
	Yamahachi FX	1.1625*	.0800	.000	.860	1.465
	SR Orthosit PE	1.0250*	.0729	.000	.734	1.316
	Yamahachi PX	1.0125*	.0800	.000	.710	1.315
	ACE Teeth	1.1500*	.0853	.000	.834	1.466
SR Orthosit PE	Cosmo HXL	-.4125	.1117	.114	-.892	.067
	Major Dent	.1375	.0565	.481	-.076	.351
	Yamahachi FX	.1375	.0565	.481	-.076	.351
	Bioform IPN	-1.0250*	.0729	.000	-1.316	-.734
	Yamahachi PX	-.0125	.0565	1.000	-.226	.201
	ACE Teeth	.1250	.0637	.805	-.122	.372
Yamahachi PX	Cosmo HXL	-.4000	.1165	.135	-.875	.075
	Major Dent	.1500	.0655	.556	-.091	.391
	Yamahachi FX	.1500	.0655	.556	-.091	.391
	Bioform IPN	-1.0125*	.0800	.000	-1.315	-.710
	SR Orthosit PE	.0125	.0565	1.000	-.201	.226
	ACE Teeth	.1375	.0718	.813	-.129	.404
ACE Teeth	Cosmo HXL	-.5375*	.1202	.022	-1.014	-.061
	Major Dent	.0125	.0718	1.000	-.254	.279
	Yamahachi FX	.0125	.0718	1.000	-.254	.279
	Bioform IPN	-1.1500*	.0853	.000	-1.466	-.834
	SR Orthosit PE	-.1250	.0637	.805	-.372	.122
	Yamahachi PX	-.1375	.0718	.813	-.404	.129

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

BIOGRAPHY

NAME	Mr. Pii Suwannaroop
DATE OF BIRTH	20 October 1981
PLACE OF BIRTH	Bangkok, Thailand
INSTITUTIONS ATTENDED	1999 – 2005, Faculty of dentistry Chiang Mai University
WORK EXPERIENCE	2005 - 2008, Dental Hospital, Khon Kaen University, Khon kaen Position: Dentist 2009 - Present, Private dental clinics, Bangkok, Thailand
RESEARCH GRANT	THE 90th ANNIVERSARY OF CHULALONGKORN UNIVERSITY FUND (Ratchadaphiseksomphot Endowment Fund)
CONTACT ADDRESS	198 M.10 Muang-nga, Muang, Lamphun 51000