ผลของแรงกดซ้ำและขบวนการเทอร์โมไซคลิง
ต่อการยึดอยู่ของสิ่งยึดชนิดบอลและโลเคเตอร์

นายกัมพล จารุศิริพัฒน์

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ปีการศึกษา 2555

THE EFFECT OF CYCLIC LOADING AND THERMOCYCLING ON THE RETENTION OF BALL AND LOCATOR ATTACHMENTS

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Prosthodontics
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กัมพล จารุศิริพัฒน์ : ผลของแรงกดซ้ำและขบวนการเทอร์โมไซคลิงต่อการยึดอยู่ของสิ่งยึดชนิดบอลและโลเคเตอร์ (THE EFFECT OF CYCLIC LOADING AND THERMOCYCLING ON THE RETENTION OF BALL AND LOCATOR ATTACHMENTS) อ.ที่ปรึกษาวิทยานิพนธ์หลัก : รศ.ทพ. ดร.แมนสรวง อักษรนุกิจ, 69 หน้า.

บทนำ : ฟันเทียมคร่อมรากฟันเทียมมีข้อดีหลายประการเมื่อเปรียบเทียบกับฟันเทียมทั้งปาก ทำให้เป็นที่นิยมมากขึ้น ปัจจุบันมีการพัฒนาสิ่งยึดที่ให้การยึดที่เพียงพอ ใช้งานและดูแลรักษาง่าย การเลือกใช้จึงต้องพิจารณาถึงคุณสมบัติของสิ่งยึด และปัจจัยต่างๆ ที่มีอิทธิพลต่อการยึดอยู่ของสิ่งยึด

วัตถุประสงค์ : เพื่อทดสอบผลของแรงกดซ้ำและขบวนการเทอร์โมไซคลิงต่อการยึดอยู่ของสิ่งยึดชนิดบอลสีเหลืองและโลเคเตอร์สีชมพู

วิธีการวิจัย : ทดสอบผลของแรงกดซ้ำ โดยทดสอบสิ่งยึดที่ฟันเทียมคร่อมสองรากฟันเทียมล่างที่ตำแหน่งฟันเคี้ยวซึ่งห่างกัน20มิลลิเมตร 2 ชนิด ชนิดละ 6 ชิ้น ดึงทดสอบ 5 ครั้ง ก่อนได้รับแรงกดซ้ำ หลังได้รับแรงกดซ้ำ 100,000, 200,000, 500,000, 700,000 และ 1,000,000 รอบ ด้วยแรง 50 นิวตัน ความถี่ 2 รอบต่อวินาที และทดสอบผลของขบวนการเทอร์โมไซคลิง โดยทดสอบสิ่งยึดชนิดละ 10 ชิ้น ดึงทดสอบ 5 ครั้ง ก่อนผ่านขบวนการเทอร์โมไซคลิง หลังผ่านขบวนการเทอร์โมไซคลิง 5,000 และ 10,000 รอบ บันทึกค่าการยึดอยู่ คำนวณค่าเฉลี่ย และวิเคราะห์ผลทางสถิติด้วยการวิเคราะห์ความแปรปรวนเมื่อมีการวัดซ้ำ ที่ระดับความเชื่อมั่น $p<0.05$

ผลการศึกษา : ค่าเฉลี่ยการยึดอยู่ของโลเคเตอร์สีชมพูมากกว่าบอลสีเหลืองทั้งก่อนและหลังได้รับแรงกดซ้ำและขบวนการเทอร์โมไซคลิง ค่าเฉลี่ยการยึดอยู่ของบอลสีเหลืองลดลงอย่างมีนัยสำคัญทางสถิติหลังได้รับแรงกดซ้ำ 700,000 และ 1,000,000 รอบ ค่าเฉลี่ยการยึดอยู่ของโลเคเตอร์สีชมพูลดลงอย่างมีนัยสำคัญทางสถิติหลังได้รับแรงกดซ้ำ 100,000 และ 1,000,000 รอบ ค่าเฉลี่ยการยึดอยู่ของบอลสีเหลืองไม่ได้รับผลกระทบจากขบวนการเทอร์โมไซคลิง ส่วนค่าเฉลี่ยการยึดอยู่ของโลเคเตอร์สีชมพูเพิ่มขึ้นอย่างมีนัยสำคัญทางสถิติหลังผ่านขบวนการเทอร์โมไซคลิง 5,000 รอบ

สรุปผลการศึกษา : ขบวนการแรงกดซ้ำมีผลทำให้สิ่งยึดบอลสีเหลืองและโลเคเตอร์สีชมพูมีค่าแรงการยึดติดลดลง แต่ขบวนการเทอร์โมไซคลิงไม่ทำให้ค่าแรงการยึดอยู่ของสิ่งยึดชนิดบอลสีเหลืองและโลเคเตอร์สีชมพูลดลง

ภาควิชา ทันตกรรมประดิษฐ์ ลายมือชื่อนิสิต

สาขาวิชา ทันตกรรมประดิษฐ์ ลายมือชื่อ อ.ที่ปรึกษาวิทยานิพนธ์หลัก

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KEYWORDS : CYCLIC LOADING / THERMOCYCLING / RETENTION / ATTACHMENT / BALL / LOCATOR

KAMPON JARUSIRIPAT : THE EFFECT OF CYCLIC LOADING AND THERMOCYCLING ON THE RETENTION OF BALL AND LOCATOR ATTACHMENTS. ADVISOR : ASSOC. PROF. MANSUANG ARKSORNNUKIT, Ph.D., 69 pp.

Introduction : Implant retained overdentures have extra advantages when compared to conventional dentures. At present, numerous types of attachments have been designed to provide adequate retention under long-term function, easy to use and maintenance. The ultimate choice of attachment type should be based on the properties and factors that influenced the retention of the attachment.

Objectives : To examine the effect of cyclic loading on the retention of yellow clix insert ball and pink Locator attachments and to investigate the effect of thermocycling and type of attachments on the retention.

Methods : Cyclic loading test: 2 implants retained overdenture with ball and Locator attachments (n=6) were subjected to 5 consecutive pulls before and after 100,000, 200,000, 500,000, 700,000 and 1,000,000 cyclic loading cycles, at 50N, 2Hz. Thermocycling test: ball and Locator attachments(n=10) were subjected to 5 consecutive pulls before and after 5,000 and 10,000 cycles of thermocycling. The retention values were averaged and statistically analyzed by 2-way repeated measures ANOVA and Tukey HSD tests at $p<0.05$.

Results : Retention of pink Locator attachments was higher than yellow clix insert ball attachments before and after cyclic loading and thermocycling. The retention of yellow clix insert ball attachments significantly decreased at 700,000 and 1,000,000 cyclic loading cycles. The retention of pink Locator attachments significantly decreased at 100,000 and 1,000,000 cyclic loading cycles. Yellow clix insert ball attachments were not significantly affected by thermocycling. And the retention of pink Locator attachments significantly increased after 5,000 thermocycling cycles.

Conclusions : The retention of both attachments decreased after cyclic loading. Yellow clix insert ball and pink Locator attachments were not susceptible to retention loss from thermocycling.

Department : Prosthodontics Student's Signature ....

Field of Study : Prosthodontics Advisor's Signature ....

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LIST OF ABBREVIATIONS

ABBREVIATIONS	DESCRIPTIONS
Ncm	newton centimeter
N	newton
p	p value
%	percent
°C	degree in Celsius
mm	millimeter
s	second
et al	et alii (and others)
ANOVA	analysis of variance
SD	standard deviation
mm/min	millimeter/minute

CHAPTER I

INTRODUCTION

Background and Rationale

More than a third of population over age 70 and more than a quarter of the population older than 65 are completely edentulous.[1] Among edentulous denture wearers, lack of retention and stability of the mandibular denture is a common problem.[2] Edentulous patients with severely resorbed mandibles may experience problems with conventional dentures due to deteriorated load-bearing capacity. Problems include pain during mastication, as well as instability and retention of the denture.[3] These can be affected by the height and shape of the mandibular ridge. The most significant biological condition associated with loss of stability and retention of complete mandibular dentures is physiological alveolar ridge resorption. Continued loss of alveolar bone can occur over time, and cause previously stable dentures to become ill-fitting. This also results in diminished oral tissue volume for denture support.[4] Deteriorating muscle strength and coordination in elderly patients may lead to problems in fabricating complete dentures, as well as difficulty in achieving and maintaining acceptable denture stability and retention. Moreover, elderly patients often have progressively decreasing neurophysiologic adaptive capacity to wearing complete dentures with an increasing age and have problems in attaining comfortable and efficient denture function.[5]

These factors cause a range of problems. Many patients experience pain when eating and chewing and are often concerned about denture moving when eating, speaking or laughing, and report fears about the negative effect of dentures on social situations.[6-8]Movement of denture can lead to concerns about aesthetics and patients also report that because of difficulty in eating foods that are difficult to bite or chew, they have to adapt their food choices, especially when eating out and in social situations. In some cases, people completely avoid social situations.[7, 8]

Overdentures have been shown to improve the quality of life for edentulous patients,[9] and contribute significantly to the patients' psychological well-being.[10] Implant supported overdentures offer better stability, retention and chewing function of the mandibular denture.[11] An overview of reported clinical trials suggests superior functional performance and patient satisfaction with implant retained complete mandibular overdentures when compared to conventional ones.[12] Previous study reported a 94.5% cumulative success rate for implants and a 100% success rate for overdentures.[13] Patients find the implant overdentures to be significantly more stable, and rate their ability to chew various foods as significantly easier. Patients also report greater satisfaction with aesthetics because the denture is not visibly moving.[11] In addition, they are more comfortable and speak more easily with implant overdentures.[14] Treatment of the completely edentulous mandible with a two-implant retained overdenture is a well-accepted treatment option.[15-17] The 2002 McGill symposium established the complete mandibular overdenture supported by two implants as the new standard of care for edentulous patients.[14]

Mastication is very important for the improvement and preservation of general health status, especially in elderly people.[18] Bite force is the most important factor influencing the efficiency of the masticatory system.[19] Objective oral function improves after treatment with oral implants, as can be seen from an increased bite force and masticatory function. The maximum bite force of subjects with a mandibular denture supported by implants was 60–200% higher than that of subjects with a conventional denture.[15-17, 20, 21] According to Lindquist and Carlsson, and Haraldson et al., the improvement in objective function seems to depend on the type of implant support for the mandibular denture.[20, 21] However, more recent studies revealed no such differences, either for chewing efficiency or for unilateral and bilateral bite force.[19]

Investigators have found that a direct relationship exists between prosthesis retention and patient satisfaction.[22] Retention and stability are the major determinants of success for mandibular two-implant overdentures[23, 24] and are a function of the specific attachment system selected to connect the implant to the overdenture.[25] The retention force is gained from mechanical and frictional contacts, or from magnetic forces of attraction between the patrices and matrices of various attachment systems.[26] Some investigators have proposed a rough estimate of 20 N of retention force is required to be adequate for mandibular two-implant overdentures,[27] similar to those reported by Maeda & Walmsley that the minimal amount of retention that provides patient satisfaction has been studied and reported to be around 8 N to 20 N for a removable prosthesis.[28] At present, numerous types of connectors have been designed to provide adequate attachment between the implants and the base of the removable prosthesis that at the same time allow simple retrieval of these restorations.[29] The ultimate choice of attachment type should be based on scientific evidence related to the clinical performance of the attachments.

One of the attachments which considered being the simplest type for clinical application with tooth- or implant-supported overdentures is ball attachment. It is indicated for non-splinted restorations in mandible. It has a special design of the clix attachment. The clix metal housing is cured into the denture and custom retention is achieved with the plastic insert, snapped into the housing. The clix inserts are available in three different strengths, offering optimal retention for every individual situation. The clix attachment is designed to virtually eliminate wear on the ball abutment and minimize the need for maintenance. The clinical process is quick and easy, changing the clix inserts to alter the retention is done easily.[30] In recent years, ball attachments have gained popularity over bars, as they are easier to manage in limited prosthetic space, more economical, easily cleansable, and less technique sensitive.[31]

Locator is a newly introduced connector design which provides accurate seating and adequate retention of implant supported overdentures.[32] It is used on non-splinted, free-standing implants. According to the manufacturer (Zest Anchors, Escondido, CA), Locator is classified as universal hinge, resilient overdenture attachments for endosseous implants. It has a low-profile height of 2.5 mm, with a diameter of 4.1 mm at their seating surface. Locator can compensate for angle corrections of up to 40 degrees.[33] It has a skirt around the denture components that permits easy location of the permanent mating component on the implant. The nylon inserts come with five different retentive holding force levels. The self-aligning feature of Locator aids patient by providing a guide plane for the removable overdenture. As a result, patient can easily align and seat the prosthesis, allowing simple and quick insertion. The Locator has extra advantages in complex cases, because it can compensate for severe angle misalignment. Previous study found that Locator provided the highest retention and stability of implant supported overdentures, followed by ball connectors and magnets, which could be advantageous in cases where the retention is compromised by other factors such as reduced residual ridges, parafunctional habits, tongue and cheek movements, and implant location and angulation.[32] Therefore, the Locator is claimed an ideal attachment for all overdenture patients.[30]

To date, the performance of varying designs of attachments has been studied in previous investigations. There are a few studies investigated the effect of mastication on the retention of ball and Locator attachments. And the change in retention values of ball and Locator attachments from thermal variations in the oral cavity has never been investigated.

Objectives

1. To examine the effect of cyclic loading and type of attachments on the retention of two-type attachment systems (ball and Locator)
2. To examine the effect of thermocycling and type of attachments on the retention of two-type attachment systems (ball and Locator)

Research Question

Do cyclic loading and thermocycling affect the retention of ball and Locator attachments?

Hypotheses

The null hypotheses of the present study were that

1. There would be no influence of cyclic loading on the retention of two-type attachments.
2. There would be no influence of thermocycling on the retention of two-type attachments.

Type of Research

Laboratory experimental research.

Research scope

This in vitro study aim to determine the effect of cyclic loading on the retention of two-implant supported mandibular overdentures retained by two-type attachment systems commonly used for two-implant overdentures, ball and Locator attachments, and investigate the effect of thermocycling and type of attachments on the retention. Two-type attachments were prepared in the same manner for cyclic loading and thermocycling, and retention values were recorded and statistically analyzed.

Agreement

This study was an in vitro experimental research which did not represent an intraoral or clinical situation. The entire study was conducted in Chulalongkorn University by one researcher using the same instrument.

Research Limitations

1. This in vitro protocol was directed at limited and specific mechanical conditions.
2. This research was affected by many confounding factors.
3. This study was costly.

Proposed Benefits

1. The results could elucidate the effect of cyclic loading and thermocycling on the retention of ball and Locator attachments.
2. The results of this implant related study could be beneficial to the dentists in designing implant supported mandibular overdentures.
3. The results could demonstrate the longevity of ball and Locator attachments which could indicate the need for routine maintenance.

CHAPTER II

LITERATURE REVIEW

Complete Dentures

Basic objectives of complete denture are the restoration of function, facial appearance, and maintenance of the patient's health. The complete denture wearer should be able to speak distinctly and experience oral comfort. Patient should also be educated in the importance of periodic examination and subsequent treatment when necessitated by change in the supporting tissue.

Mastication of food with complete denture assists the edentulous patient in obtaining adequate nutrition. However, complete dentures constructed even under the most ideal conditions will have a chewing efficiency of only a fraction of that of the natural dentition.[34]

When teeth are lost, patient often experience difficulty with prosthesis. The alveolar ridges, hard palate and buccal shelves used for support and retention can provide only a poor substitute for the masticatory efficiency of the natural dentition. Tolerating conventional complete dentures, particularly in the lower arch, can be difficult for many patients who may experience problems with retention and stability.

Factors that adversely affect successful use of a mandibular complete denture include: mobile tissues of the floor of mouth, atrophic alveolar mucosa covering the residual ridge, reduced bony support, muscular factors, and age of patient and its influence on adaptation.

Wearing maxillary complete denture is usually less problematic than mandibular because of the inherent displacing movement of the tongue and muscular borders. The palate also provides a relatively stable base and wide surface area with thick fibrous tissues. These lend support to the prostheses and help resist occlusal forces. Reduction in the volume of oral tissue because of residual ridge resorption compromises the retention of dentures. It has been demonstrated that the edentulous mandible may lose up to four times more bone volume than the edentulous maxilla.[35] In the past, several methods have been employed to augment the quality of the supporting tissues; these included vestibuloplasty, ridge augmentation and grafting procedures. These methods have met with variable success, and since the advent and success of osseointegrated implants, have fallen out of vogue.

Implant Retained Overdentures

Conventional dentures will not meet the desires or needs of all patients. The use of osseointegrated implants to substitute for missing teeth was developed by Branemark over 40 years ago[36] and several studies have demonstrated the success of this treatment modality.[37-39] An implant retained overdenture is a removable dental prosthesis supported by the residual oral tissues and retained by dental implants. This concept has been successfully used for over 30 years.[40]

Implant retained overdentures demonstrate improved retention and stability when compared to conventional dentures.[11, 31] Implant retained overdentures may reduce residual ridge resorption and improve chewing function, nutritional status, speech and patient confidence.[11, 41] It has been shown that, in some patients, the functional and psychosocial limitations seen with mandibular complete dentures are significantly improved by using implants to stabilize mandibular overdentures.[29, 42] Furthermore, implant retained removable complete overdentures offer an effective rehabilitation for the edentulous mandible.[43] This type of prosthesis should be considered in all patients unable to tolerate conventional dentures. They may be specifically indicated in patients with altered anatomy following surgery, neuromuscular disorders, a pronounced gag reflex or severe residual ridge resorption.

Although there may be marked resorption of the mandibular residual ridge, there is usually sufficient basal bone anteriorly to accommodate implants. Implant placement may, indeed, help to prevent or decelerate further bone loss. The anterior mandibular bone under an implant overdenture may resorb as little as 0.5 mm over a 5-year period, and long-term resorption may remain at 0.1 mm annually.[44]

For centuries, conventional complete dentures have been the only treatment for edentulous patients, but now there has been a move to make a maxillary conventional denture over a two-implant retained mandibular overdenture, the new minimum standard of care.[43] It has been shown that a two-implant retained overdenture provides significantly greater patient's satisfaction,[29, 45] masticatory function and oral health-related quality of life than new complete conventional dentures.[29, 42] In addition, it has been shown in a recent cost effectiveness study that the substantial clinical benefit of this type of implant overdenture, when compared with conventional dentures, can be obtained at a relative modest incremental cost.[46] A 97% implant survival with two implants, irrespective of keratinized tissue or duration of edentulism, has been reported.[47] Therefore, it has recently been recommended that the restoration of the edentulous mandible supported by two implants is the gold-standard treatment.[43]

Type of Attachments

Splinted System

Bar Attachment

A splinted system uses plastic or metal clips cured into the denture base to engage a metal-alloy bar connected rigidly to both implants. This option is recommended when the implants are not parallel or more than two implants are present. This system has been shown to provide the best retention.[48] A recent randomized control trial concluded that an overdenture on two implants interconnected by a single bar may be the first treatment of choice, with high cost-effectiveness, efficacy, stability and good long-term patient satisfaction. However, there are several notable disadvantages of this attachment which include difficulty in maintenance, the necessity of the retention clip's activation, and the increased horizontal space requirement within the denture base that can predispose the denture to fracture. It can also be difficult to replace the attachments or reline the denture. Gingival hypertrophy beneath the bar may be problematic as oral hygiene procedures may be more difficult.[49]

Milled bars do not allow movement of the denture base. They provide excellent retention and stability and can provide relief over painful areas such as superficial mental nerves. However, they are expensive, difficult to repair and derive limited mucosal support, which may overstress attachments and predispose to mechanical complications. Resilient bars, when appropriately designed, allow a single axis of rotation, utilize greater mucosal support, and offer greater protection to the retentive attachments. Both designs of bar may be used to align non-parallel implants. However, they require at least 10 mm of interocclusal clearance and should not be used where vertical space is limited. Both designs of bar may be associated with soft tissue hyperplasia.[50]

Waddell and colleagues evaluated the failures of bars in the maxillary overdentures. Prosthodontic maintenance requirements throughout the two years of the bar units revealed only one bar fracture in year 1 and two bar fractures in year 2. A total of 3 fractured bars as well as 2 additional intact bars revealed signs of stress corrosion. In the fractured bars, evidence of corrosion was demonstrated.[51] Goodacre and colleagues reported the incidence of the overdenture clip/attachment fracture as 16%. In this study, 1 bar fracture occurred in the mandible. The possible cause was the lack of parallelism of implants.[52]

Non-Splint System

Ball Attachment

Ball attachment was considered the simplest type of attachments for clinical application with tooth-or implant-supported overdentures.[53] The ball attachment consists of a spherical patrix that is usually attached to the implant. The matrix is housed inside the denture base and fits over the patrix. This provides retention by means of spring-action arms or an interchangeable elastic ring. The ball attachment offers good retention and support and relatively easy maintenance. It has been shown that ball attachments are less costly, less technique sensitive, and easier to clean than bars. Furthermore, the potential for mucosal hyperplasia is reduced with ball attachments. Balls are relatively bulky within the denture and need generous vertical space to allow for all retentive components. They may be a suitable choice if the implants are divergent. Two-implant retained mandibular overdentures using ball attachments have also been found to improve the nutritional state of edentulous patients.[54]

Sadowsky reported that solitary ball attachments appear to be less costly and less technique sensitive. However, ball attachments seem to be less retentive than the bar design.[44]

Locator Attachment

Locator attachment (Zest Anchors, Escondido, CA) which was introduced in 2001, is a new system, which does not use the splinting of implants. This attachment is self-aligning and has dual retention (inner and outer). Its design features the benefits of the minimal height requirement (3.7 mm) and greater cross-section for strength. Locator attachments come in different colors and each has a different retention value (clear, pink, blue, green, orange, red) and available in different vertical heights. The white attachment has standard retention, the pink has light retention, and the blue has extralight retention. They are resilient, retentive, durable, and have some built-in angulation compensation, which can be used to correct implant angulation up to 20◦. In addition, repair and replacement are fast and easy.[5, 55, 56]

Chung et al compared the retention characteristics of 9 attachment systems including pink and white Locator attachments with the Hader bar and metal clip

(APM-Sterngold), Spheroflex ball (Preat Corp., San Mateo, CA), Shiner SR magnet (Preat Corp.), Maxi 2 magnet (Golden Dental Products, Inc., Savannah, GA), Magneidisc 800 magnet (Aichi Steel Corp., Aichi-ken, Japan), and white ERA and gray ERA attachments (APM-Sterngold). Two parallel implants were used. An overdenture metal framework was fabricated. The linear dislodging movement was obtained using 3 chains attached to the framework. The values were recorded for 5 specimens of each attachment system. The peak-load-to-dislodgement values ranged from 3.68 N to 35.24 N, the Locator pink mean value was 12.33 N and the Locator white value was 28.95 N. The magnets exhibited the lowest retention values and the ERA gray the highest with a mean value of 35.24 N.[5] Rutkunas et al compared the retention forces of a 2 parallel implant configuration system using 9 different attachment systems including the Locator root pink (LRP). The LRP is designed for a root supported overdenture. They evaluated and compared the retentive and stabilizing properties of the 9 systems in linear and rotational dislodgment forces. Ten measurements were collected for different dislodging forces. A 10 second pause was observed to allow for recovery of the resilient parts of the attachment systems. They found that the magnetic attachments had considerably lower retentive energy values for all type of dislodgments compared to stud attachment systems. The LRP exhibited a maximum linear retentive force of 10.58 Newton (N), a result comparable to the Era white and Era Orange attachment system. The maximum linear retentive force was measured in a one implant parallel to vertical configuration.[57]

In another study, the same authors evaluated the fatigue of 5 attachments systems including the LRP by measuring maximum retentive force in a one implant design parallel to vertical. They performed 2000 insertion-removal cycles to determine the number of cycles required to reach a stable retention. Initially, the LRP, and the Era orange and white presented an important loss of retention value (within the first 100 cycles). They all reached a stable retention value after 800 cycles. The LRP had the best fatigue resistance with an approximate loss of 30% in retention after 2000 cycles and the final retentive force was 6 N, the best value of all the attachment systems evaluated. All the attachment systems lost retention due to fatigue. The retentive properties of studs were more susceptible to fatigue than that of magnetic attachments.[58]

The same authors evaluated 9 attachment systems including the LRP. The 800 cycle value was determined to be the landmark in their previous studies as far as stabilization of the retention forces. All specimens (12 per group) were tested in linear and rotational dislodgement for 10 values with a pause of 10 seconds between each record. They were all submitted to 800 cycles to simulate wear. The values in linear and rotational dislodgements were recorded again for comparison purposes. A statistically significant decrease of the retention range after wear simulation was noticed for all studs except LRP. The dislodgement movements were done with a 2 parallel implants configuration. They found the LRP to be less sensitive to wear (24% of initial value) and the retention of overdenture to be best ensured by LRP compared to other attachment systems. The retention of the LRP in linear dislodgement after wear simulation was 8.0 N.[59]

Magnetic Attachment

Magnets have generated great interest within Dentistry, and their applications are numerous. The two main areas of their use are orthodontics[60, 61] and removable prosthodontics. The use of attractive force between two magnets for denture retention was reported in early 1960s. The reason for their popularity is related to their small size and strong attractive forces; these attributes allow them to be placed within prostheses without being obtrusive in the mouth. Despite their many advantages, which include easy to incorporate into a denture and can simplify both clinical and technical procedures, ease of cleaning, ease of placement for both dentist and patient, automatic reseating, and constant retention with number of cycles, magnets have limitations which are related mainly to their lack of longevity due to poor corrosive resistance within oral fluids, loss of magnetism, and their expense in comparison to other systems.[62-64] Both Sm-Co and Nd-Fe-B are extremely brittle and susceptible to corrosion, especially in chloride-containing environments such as saliva. The corrosion products from rare earth magnets also have been shown to have cytotoxic effects in in vitro tests.[65, 66]

The first attempts at using magnets to retain dentures involved implanting them within the jaw; problems ensued because of the large size of the magnets and the inadequate forces that they provided. As material technology improved, smaller magnets were made that could be incorporated into retained roots with similar units built into the denture. Later developments included the replacement of the root magnet with a soft magnetic material that is magnetized while the denture is in place but returns to a demagnetized state on removal of the denture. In the last 20 years, the design of magnetic attachments has changed to reduce the external magnetic fields present while the denture is in place. Improvements in magnetic materials have allowed smaller and more powerful magnetic attachments to be produced from Sm-Co and Nd-Fe-B alloys.[63, 67]

An implant supported overdenture with magnets comprises magnets incorporated into the denture acting upon keepers attached to implant abutments.[68] Retention depends upon the forces of attraction between the magnets and the keepers.[69] Small movements of the denture during function can break contact between the magnets and the keepers. Some patients tolerate this well, however, a number of patients find this produces an annoying clicking sound.[64] Magnets are advantageous in areas where space is at a premium and are relatively easy to maintain. For optimal performance of magnet attachment systems, relatively good parallelism and correct angulation of the implants is required.[69]

Factors Influence the Retention of Overdentures

Different attachment systems provide varying degrees of resiliency, both in horizontal and vertical directions with varying degrees of wear over time.[27, 70-73] It has also been demonstrated that most attachment systems suffer from wear during insertion and removal as well as under functional load.[72-75] Factors that influence the retention of overdentures are described below.

Insertion and Removal

Gamborena et al investigated the retentive force of four color-coded ERA attachments (Sterngold) both initially and up to 5,500 insertion-separation cycles, simulating 3 years of clinical function. The patrices and matrices were of plastic and metal composition, respectively. A mean retentive force range between 1.52 N and 2.52 N was reported at baseline for all four types of attachments. At the conclusion of the wear simulation test, a dramatic loss of retention was observed across all four types of attachments, with an overall loss of 85% to 88% of the initial retentive force.[71]

Upon microscopic measurement (Nikon Measurescope 20), Fromentin et al observed distinct wear patterns characterized by distortion of the plastic patrices. The metallic matrices, on the other hand, appeared unchanged. The wear-induced changes in the dimensions of the plastic patrices were thought to have caused the eventual loss of retention observed with these attachments. Similar observations were also reported with other attachment systems.[70]

Walton and Ruse compared retentive forces of metal bars with metal clips on the one hand with metal bars and plastic clips on the other and found that both systems provide retentive forces between 10 and 14 N and described loss of retention of 10% to 20% after 5500 cycles.[74]

Implant Angulation

Attachments on parallel implants would be less susceptive to retention loss than those on fixtures with excessive angulations.[76] Previous studies found that implant angulations influence retention force after applying insertion-removal cycles on the Locator system.[77, 78]

The retentive force of ball attachments was found to decrease with an increase in implant angulation. Optimum retentive force would therefore be expected with the attachments in a vertical alignment to the implants.[69] A 30- degree implant angulation was reflected in a reduction in the retentive force up to 25%. However, this reduction is of little clinical significance and does not warrant the use of other means of retention to circumvent implant malalignment. Others demonstrated that with implants diverged up to 60 degrees, ball attachments can still provide adequate retention. It should be noted here that this study did not conduct retentive force recordings and the retention of these attachments at this angulation was only assessed subjectively by exerting manual pulls.[79]

Nonparallel implants, when used to retain overdentures, may present a restorative challenge, particularly when using attachments. Premature wear of the components and loss of retention may be observed, resulting in increased maintenance. Ortegón et al compared the retentive behavior, over time, of spherical attachments when used in nonparallel and parallel implant scenarios in insertion-removal cyclic testing mode. Angulation was determined by deviation from the vertical reference plane. The results showed there was a decrease in retention in the groups with 30-degree divergent implants and divergent attachments compared to the groups with parallel implants and parallel attachments. In general, retention varied from 11 N to 23 N, and attachment retention stabilized after initial loss in most groups.[80]

Implant Number

Overdentures may be retained by a varying number of implants, which may be splinted or freestanding.[81] Studies investigating mandibular overdentures have reported high implant survival rates and treatment success rates when overdentures are retained by either two or four implants.[40, 81, 82] Originally, implants retaining mandibular overdentures were splinted to distribute stresses and protect the bone implant interface.[83] However, later studies have suggested that this is unnecessary. A recent systematic review by Galluci et al reported that mandibular overdentures retained by two unsplinted implants in the canine regions were as successful as four splinted implants.[84] This statement appears true regardless of whether the implants are conventionally or immediately loaded.[85, 86] It has even been reported that lower implant overdentures can be successfully retained by a single implant. However, this is not advocated as a mainline treatment strategy. Two freestanding implants in the canine regions, as the simplest option, would appear the treatment of choice to retain an overdenture in the edentulous mandible.[87]

Traditionally, implant-retained overdentures have performed poorly in the maxilla. This has been attributed to relatively poor bone quality and quantity, increased implant to abutment ratios and non-axial loading.[31] As a result, a greater number of implants are normally placed in the maxilla. Several reviews have concluded that there is little evidence to support any approach, other than the delayed loading of 4–6 splinted implants in the maxilla.[31, 84] When this approach is used, implant survival rates of 94.8–97.7% after 10 years have been reported. However, freestanding implants have also been successfully used to support implant-retained overdentures in the maxilla. Ideally, implants in the maxilla should be widely distributed, symmetrically about the arch. However, this may be complicated by pneumatization of the maxillary sinus, alveolar orientation and ridge morphology.[84]

Mastication

Mastication may cause different patterns of wear and deformation of the attachment systems when compared to insertion and removal as occlusal loads can easily induce displacement of the mucosa under the denture base higher than 1 mm,[88] forcing the denture to rotate around the attachments.[89] Parafunction may also be present in different intensities and might influence the clinical performance of attachment systems.[76] Furthermore, the degree of occlusal load concentrated on the attachments will depend on their resilience.[90-92]

Breeding et al investigated the retention of bar attachments before and after simulated mastication. A slight increase in the retentive strength was found after an attempt to simulate 1.75 years of function.[75]

Abi Nader assessed the effect of simulated mastication on the retention of two stud attachment systems for two-implant overdentures. Sixteen specimens, each simulating an edentulous ridge with implants and an overdenture were divided into two groups, according to the attachment system: Group I (Nobel Biocare ball-socket attachments) and Group II (Locator attachments). Retention forces were measured before and after 400000 simulated masticatory loads in a customized device. Group I presented significantly lower retention forces (Newtons) than Group II at baseline (10.6 ± 3.6 and 66.4 ± 16.0, respectively). However, differences were not significant after 400000 loads (7.9 ± 4.3 and 21.6 ± 17.0). The number of cycles did not influence the measurements in Group I, whereas a non-linear descending curve was found for Group II. It was concluded that simulated mastication resulted in minor changes for the ball attachment tested. Nevertheless, it reduced the retention of Locator attachments to 40% of the baseline values, what suggests that mastication is a major factor associated with maintenance needs for this system.

It was expected that the tested systems would present distinct mean retention forces at baseline, as long as both present different retentive mechanisms. In contrast to Group I (ball-socket attachments) attachments, which present retention around a ball-shaped portion, Group II (Locator attachments) attachments have retentive areas on both their external and internal surfaces, thus providing wider contact surface between matrices and patrices. Moreover, the cylindrical shape of components provides additional retention, as long as the retentive areas are adjacent to parallel surfaces. It seems that the extent of retentive areas and the convergence of adjacent areas are important factors for the initial retention forces found in this study.

Simulated mastication did not change retention forces significantly for Group I (ball-socket attachments), despite the lower initial values. Those findings contrast with the non-linear loss of retention associated with repeated insertion-removal cycles. They also indicate that mastication does not cause important changes in the tested ball attachments, opposed to what happens after repeated removal of an overdenture. SEM analysis found some microscopic changes, which clearly are signs of wear on the matrices and patrices. Nevertheless, those changes are slighter than those found in other study after repeated insertion-removal cycles and were insufficient to alter retention forces.

Group II (Locator attachments) presented non-linear changes in response to the increasing number of simulated masticatory loads. Retention force was even until 100000 loads, but suffered a loss of approximately 60% from that point to 300000 loads. Other studies found loss of retention ranging from 30 to 80% for the Locator attachment system following repeated insertion-removal cycles. Despite the difficulties inherent to comparison among different methods, it is evident that masticatory loads cause important changes in the attachment as previously found for insertion-removal cycling. Loss of retention after cycling was also observed for other attachment system based on cylindrical patrices and polymeric components in the matrices, i.e. ERA system.[76]

Attachment Material

Material selection for attachment systems should ideally allow for provision of adequate retention under long-term function. Preference for certain material combinations in attachment systems based on the reviewed literature remains inconclusive. The findings from two reports where an objective assessment of wear changes was attempted implied that polymeric (plastic, nylon, and rubber) components of attachment systems were more susceptible to wear than metallic ones. The structural changes observed in these components have been previously described to result from thermal expansion under cyclic loading in wet conditions.[73] The failure to demonstrate wear changes within the metallic components, however, could be related to either the minute magnitude of these changes or the limitations of the investigative methods employed.[70, 71]

Attachment systems of purely metallic components were indeed demonstrated to endure retention loss subsequent to wear simulation in several reports.[27, 93, 94] Furthermore, physical properties of attachment alloys (modulus of elasticity in particular) were said to modulate the wear behavior of these attachments.[95]

Attachment Design

Poor retentive force performance of certain attachment designs (titanium matrices with stainless steel metal springs) was reflected by significant fluctuations and a subsequent loss of retention.[69, 93] These findings were in accordance with those reported in several clinical studies using this particular attachment design where substantial maintenance was needed.[96, 97]

Attachment systems must ideally be of a simple design and preferably made of as few components as possible, particularly in their retentive elements.[69] This was thought to ensure consistent and predictable retention. Of equal clinical benefit is that ball attachments designed with matrices capable of free rotation over the patrices (eg, Straumann retentive anchors and ball attachments from Nobel Biocare and Astra Tech) were found to be tolerant to implant malalignment. The free movement of these matrices allows for their parallel alignment in relation to each other within the denture base and to the path of insertion and removal, irrespective of implant parallelism to certain extents.[79] Ball attachments with parallel-walled patrices, those with locking systems, and others with matrices engaging deep undercuts would conversely provide only limited flexibility.

CHAPTER III

METHODOLOGY

Part I: The retention of ball and Locator attachments retained mandibular overdentures after cyclic loading

Fabrication of Two-Demo Implant Edentulous Mandibular Model

A model was fabricated in dental stone (Whip mix, Louisville, KY) to simulate an edentulous mandible. No undercuts were present in the model. All edentulous area was reduced 2 mm in height for simulation of soft tissue. Two 4.5/5.0 parallel implant replicas (Astra Tech AB, Mölndal, Sweden), 15.5 mm in length, were placed in canine region (20 mm apart), with Astra Tech implant guide pin in place to visualize positioning and angulation, using a surveyor (The J.M. Ney Company, Hartford, CT). Two 4.5/5.0 implant transfers (Astra Tech AB, Mölndal, Sweden), 21 mm in length, were tighten securely into the implant replicas. Then a silicone mold (Dentsply, Milford, DE) of mandibular model with two implant transfers was made. Two 4.5 x 11.0 mm demo implants (Astra Tech AB, Mölndal, Sweden) were fixed with the implant transfers. An epoxy resin (Rungrojfiberglass, Samutprakarn, Thailand) was poured into the silicone mold, then epoxy resin made edentulous mandibular model with two demo implants in canine region was fabricated (Fig.1), and polyvinylsiloxane material (Reprosil; Densply Caulk, Milford, DE) was used to simulate soft tissue (Fig.2).

Figure 1 Edentulous mandibular model with two demo implants

Figure 2 Soft tissue model with two abutments on demo implants

Two commonly used attachment systems for two-implant overdentures, ball attachments (Ø 2.25 mm, 2.00 mm in height) and Locator attachments (Ø 3.85 mm, 2.00 mm in height) were used in this study. Abutments were installed into demo implants and torqued to 25 Ncm.

Fabrication of Mandibular Overdentures

Abutment pick-up was attached firmly to each abutment and checked to ensure that it was securely in place and had stable friction retention. A customized impression tray was used to take the abutment-level impression with a polyether impression material (Impregum; 3M ESPE, Saint Paul, MN). Abutment replicas were firmly placed into the abutment pick-ups. Then a working model with abutment replicas was fabricated in dental stone. A wax occlusion rim was fabricated with autopolymerizing acrylic resin (Bosworth company, Skokie, IL) and modelling wax (Dentsply, Surrey, England). Acrylic resin teeth (Yamahachi Dental MFG, Aichi Prefecture, Japan), (L5, A3) and (M30, A3) were arranged in anterior and posterior position, respectively. After waxing, a stone index was made as an index for teeth arrangement of the other eleven overdentures. A raised wax platform was built lingual to anterior teeth. A spacer was placed over the head of each abutment replica, then flasking and wax elimination. A processing cap was attached firmly to each abutment replica, using surveyor, then processed and cured into an overdenture with heat-curing acrylic resin (SR Triplex Hot; Ivoclar Vivadent AG, Liechtenstein) (Fig.3).

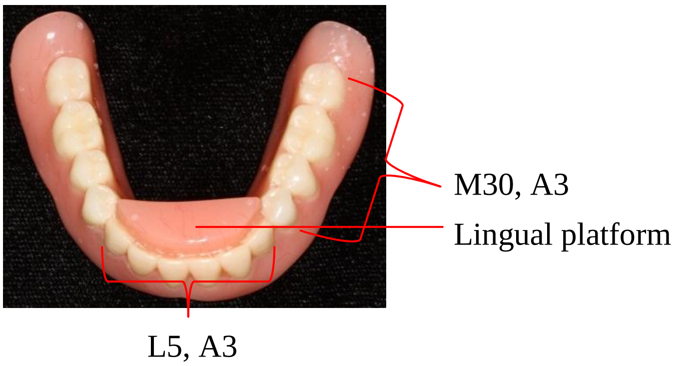

Figure 3 Overdenture with raised acrylic platform lingual to anterior teeth

Twelve edentulous mandibular models were constructed for fabrication of six yellow clix insert ball and six pink Locator attachment retained overdentures.

Cyclic Loading

A stainless steel rod and platform was designed and milled. Upper right and left posterior teeth (second premolar, first molar and second molar) were attached on the platform with self-cure acrylic resin (Tokuso Cure Fast; Tokuyama, Tokyo, Japan). The stainless steel rod was fixed to a universal testing machine (Instron 8872; Instron Coporation, Norwood, MA). The upper posterior teeth were positioned in contact with lower overdenture on the epoxy resin model (Fig.4, 5). When force of 10 N was loaded, all upper teeth were in contact. The occlusal contacts were confirmed by 8 μm shim stock (Fig.6).

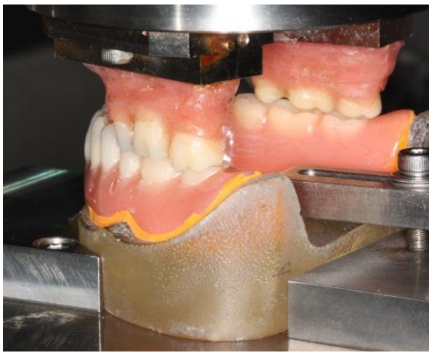

Figure 4 Outer view of posterior teeth

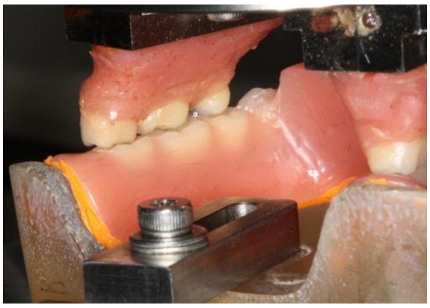

Figure 5 Inner view of posterior teeth

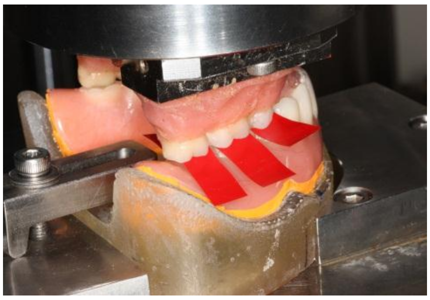

Figure 6 All upper teeth were in contact when checked with shim stock

Compressive cyclic loads were applied to mandibular overdentures at 50 N,[98] 2 Hz sampling rate, 0.20 mm amplitude control, and 1,000 N load cell. All mandibular overdentures were subjected to 1,000,000 cyclic loads. The test was performed in 37 ºC distilled water in circulating water bath. A survey revealed that the average number of chewing cycles is about 800,000 per year.[99] Therefore, one million cycles were selected in this study corresponded to an in vivo service period of approximately 15 months.

Retention Test

The retention test was designed to exert a vertical dislodging force to the overdenture. A square stainless steel plate, 25 mm in width, 45 mm in length, and 1 mm thick, was inserted into raised acrylic platform of overdenture, on a line running through the center of both implants. The plate was held perpendicular to the overdenture, with the aid of surveyor. An upper grip connected the universal testing machine to the top of stainless steel plate to facilitate engaging the overdenture to the upper connecting jig of the load cell (Fig.7). The tensile mode was used with 1,000 N load cell and crosshead speed of 50 mm/min. This speed approximates the actual speed of removal of an overdenture away from its retentive elements in the mouth under a vertical dislodging force.[100] Each overdenture was subjected to 5 consecutive pulls, with a resting period of 4 minutes between each pull and averaged. The retention forces, the maximum force when the attachment components were separated, were collected at baseline (0) and after 100,000, 200,000, 500,000, 700,000 and 1,000,000 cyclic loading cycles.

Figure 7 A stainless steel plate connected the overdenture to the universal testing machine

Statistical analysis

All data were statistically analyzed with statistical software package (SPSS for Windows; SPSS Inc., Chicago, IL). Two-way repeated measures ANOVA and Tukey HSD tests were used to analyze the difference in retention values at $p<0.05$.

Part II: The retention of ball and Locator attachments after thermocycling

Fabrication of acrylic resin block with demo implant and attachments

A silicone mold (Dentsply, Milford, DE) 7x7x20 mm rectangular shape with 7x4x10 mm handle was fabricated. A demo implant (4.5x11mm) (Astra Tech AB, Mölndal, Sweden) with wax guide pin was set in the middle of the silicone mold, perpendicular to the floor, using a surveyor (Dentsply, Bloomfield, CT). Autopolymerized ortho clear acrylic resin (Lang Dental Manufacturing Co., Inc., Wheeling, IL) was poured into the silicone mold to fabricate implant block. The top of the implant was set at the same level as the top of the block. The ball (Astra Tech AB, Mölndal, Sweden) (Fig.8) and Locator abutment (Zest Anchors, Escondido, CA) (Fig.9) were screwed into the demo implant with torque wrench at 25 Ncm. Then ten yellow clix insert ball attachment (Astra Tech AB, Mölndal, Sweden) blocks and ten pink Locator attachment (Zest Anchors, Escondido, CA) blocks were made in the same manner, and a hole (Ø 2mm) was drilled into the handle of all attachment blocks (Fig.10).

Figure 8 Schematic diagram of structure of ball attachments; height of ball attachment - 2.00 mm, diameter of ball attachment - 2.25 mm.

Figure 9 Schematic diagram of structure of Locator attachments; height of Locator attachment - 2.00 mm, diameter of Locator attachment - 3.85 mm.

Ten attachment blocks contained a clix female with yellow clix insert ball embedded in it (Fig.10). And another ten attachment blocks contained a Locator cap with pink nylon.

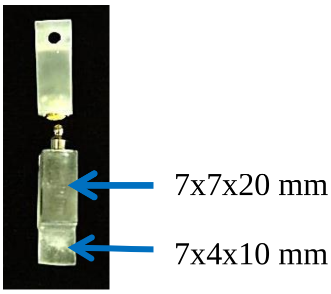

Figure 10 An implant block and attachment block

Thermocycling procedure

Twenty attachments were subjected to thermocycling (Medical & Environmental Equipment Research Laboratory Technology Ladkrabang, Bangkok, Thailand) for 5,000 and 10,000 cycles between 5°C and 55°C with a 30-second dwell time and a transfer time of 15 s. The temperature range between 5°C and 55°C was chosen to simulate the temperature of foods ingested during meals without damaging oral tissues.[101]

Retention test

After 0, 5,000 and 10,000 cycles of thermocycling, each attachment was then removed from the storage container, dried with paper towel, and fixed in a table-top of the universal tester (Shimadzu EZ-S-500N, Tokyo, Japan) (Fig.11). A tensile load was applied using 500 N load cell and a crosshead speed of 50 mm/min. Each attachment was subjected to 5 consecutive pulls, with a resting period of 4 minutes between each pull and averaged. The machine was equipped with a computer interface software package (Trapezium2) which contained a tensile application module. The retention forces were collected, and mean retention values were calculated.

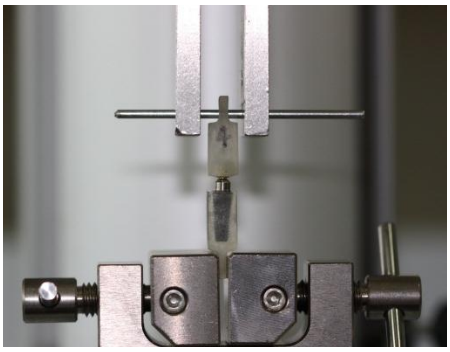

Figure 11 Attachment was fixed in a table-top universal tester

Statistical analysis

All data were statistically analyzed with statistical software package (SPSS for Windows; SPSS Inc., Chicago, IL). Two-way repeated measures ANOVA and Tukey HSD tests were used to analyze the difference in retention values at $p<0.05$.

CHAPTER IV

RESULTS

Part I: The retention of ball and Locator attachments retained mandibular overdentures after cyclic loading

Two-way repeated measures ANOVA revealed significance on two main effects; cyclic loading ($p<0.005$), type of attachment ($p<0.001$) (Table 1). The retention values of yellow clix insert ball attachments and pink Locator attachments are illustrated in Figure 12 and 13, respectively. Each box plot represents the retention values of the attachments tested. At baseline, the retention value of pink Locator attachments (36.54± 3.99 N) was significantly greater than yellow clix insert ball attachments (18.82± 2.91 N).

Source of Variation	DF	SS	MS	F	P
time	5	158.733	31.747	4.505	0.005
type	1	6155.321	6155.321	75.968	<0.001
time x type	5	41.629	8.326	1.210	0.333

Table 1 Statistical analysis of two main effects; cyclic loading and type of attachment

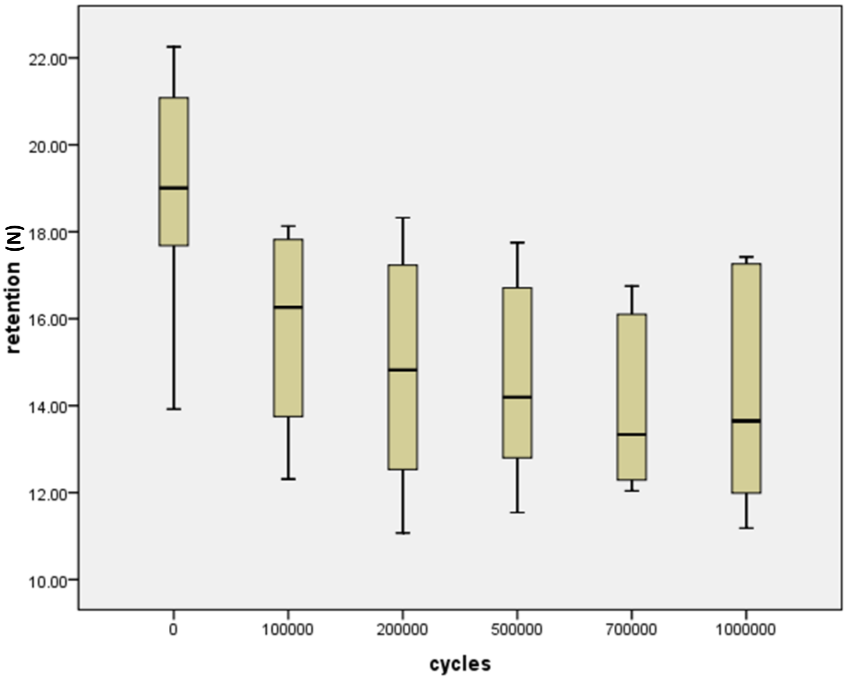

Figure 12 The retention values of yellow clix insert ball attachments at the cycling intervals

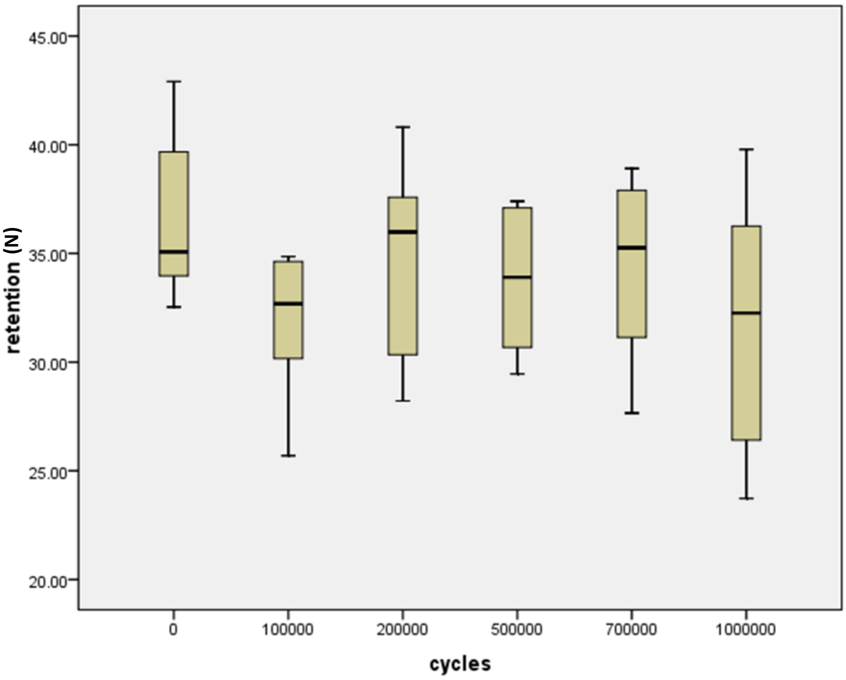

Figure 13 The retention values of pink Locator attachments at the cycling intervals

The mean retention values of yellow clix insert ball attachments at 100,000, 200,000 and 500,000 cycles were insignificantly different from baseline. At 700,000 cycles, the mean retention value significantly decreased from baseline and remained stable to 1,000,000 cycles (Fig.14).

The mean retention value of pink Locator attachments at 100,000 cycles decreased significantly from baseline. Then the mean retention values increased after 200,000, 500,000 and 700,000 cycles, and they were insignificantly different from the mean retention value at baseline. After that, the mean retention value decreased at 1,000,000 cycles and it was significantly different from the mean retention value at baseline (Fig.14).

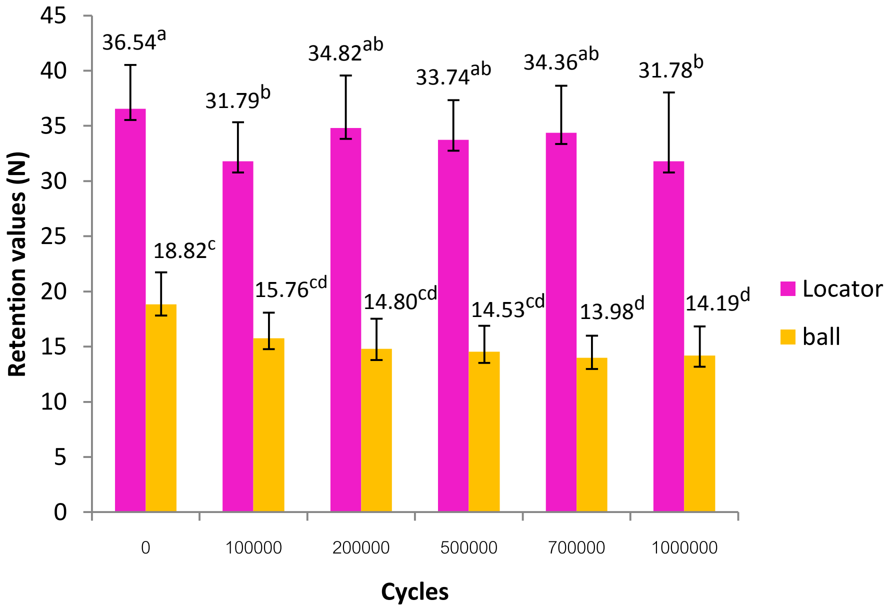

Figure 14 Means and standard deviation of retention values of yellow clix insert ball and pink Locator attachments at different cyclic loading cycles. Groups with the same superscript letter were not significantly different (p>0.05).

Part II: The retention of ball and Locator attachments after thermocycling

Two-way repeated measures ANOVA revealed significance on two main effects; thermocycling, type of attachment, and interactions (p<0.001) (Table 2). The retention values of attachments tested are illustrated in Figure 15 and 16. Each box plot represents the median retention value of the attachments tested. Pink Locator attachments presented significantly greater retention values than yellow clix insert ball attachments at baseline (16.58±1.86 N and 12.89±2.25 N, respectively).

Source of Variation	DF	SS	MS	F	P
cycle	2	346.666	173.333	59.576	<0.001
type	1	1998.370	1998.370	274.254	<0.001
cycle x type	2	462.147	231.073	121.162	<0.001

Table 2 Statistical analysis of two main effects; thermocycling and type of attachment

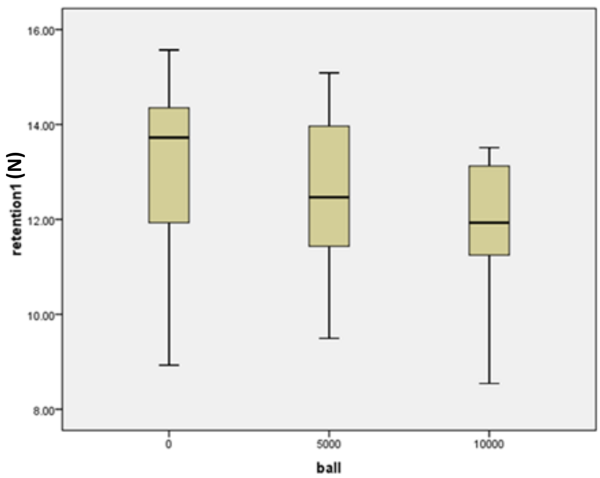

Figure 15 The retention values of yellow clix insert ball attachments at the thermocycling intervals

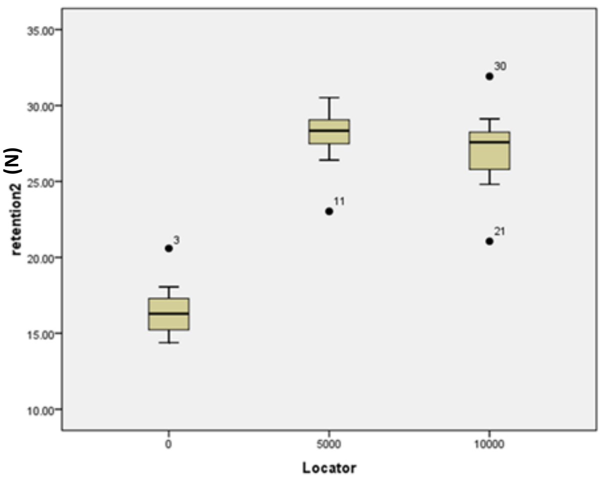

Figure 16 The retention values of pink Locator attachments at the thermocycling intervals

The mean retention values of yellow clix insert ball attachments slightly decreased from baseline (0 cycle) (12.89±2.25 N), to 5,000 thermocycling cycles (12.44±1.87 N) and lowest at 10,000 cycles (11.66±1.57 N), the reduction were not significantly different (Fig.17).

On the contrary, there was a significant difference in the mean retention values of pink Locator attachments from baseline to after 5,000 thermocycling cycles. The mean retention value was lowest at baseline (0 cycle) (16.58±1.86 N) and exhibited the highest mean retention value at 5,000 thermocycling cycles (27.98±2.11 N) and slightly decreased at 10,000 cycles (27.64±1.95 N), which was not significantly different from the mean retention value at 5,000 cycles (Fig.17).

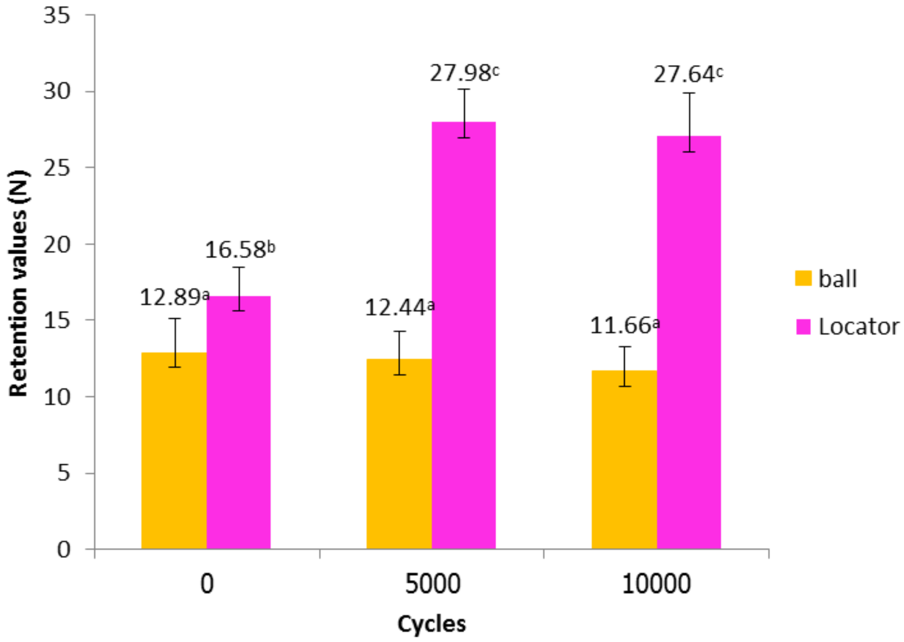

Figure 17 Means and standard deviation of retention values of yellow clix insert ball and pink Locator attachments at different thermocycling cycles. Groups with the same superscript letter were not significantly different (p>0.05).

CHAPTER V

DISCUSSION

It was assumed that 20 N of retention force is probably sufficient for mandibular two-implant overdentures.[102] Therefore, yellow clix insert ball (11.50 N of retention holding force) and pink Locator (13.61 N) attachments were evaluated in this study. Furthermore, pink Locator attachments were tested because they were the most commonly used attachments in practice.[103]

This study divided into two parts. The first aim of this study was to examine the effect of cyclic loading and type of attachment on the retention of two-type attachment systems (ball and Locator). Statistical analysis revealed significant differences of the two main factors; cyclic loading and types of attachment. Therefore, the null hypothesis was rejected.

The results showed that the retention of pink Locator attachments was greater than yellow clix insert ball attachments before and after cyclic loading, and the retention of two-type attachment systems were affected by cyclic loading. The retention of yellow clix insert ball attachments was not affected at 100,000, 200,000 and 500,000 cyclic loading cycles, but the retention decreased after 700,000 cycles and remained stable up to 1,000,000 cycles. The retention of pink Locator attachments decreased with a higher rate from the beginning to 100,000 cycles, this might be due to the wear of the attachment components from cyclic loading. After that the retention increased at 200,000, 500,000 and 700,000 cycles. The increase of retention may relate to the experimental setting of this study. Cyclic loading test was performed in water, the nylon components may uptake water, caused enlargement. This might contribute to an increase of retention. And at the end of cycles, alterations of the attachment’s components from long-term cyclic loading may result in the decrease of the retention of the attachments.

The fabrication of two-demo implant edentulous mandibular model, soft tissue was simulated 2 mm in height with polyvinylsiloxane material to provide movement of the denture. This height was used since the effectiveness of implant placement in the thick soft tissue (2 mm) was greater than for the thin soft tissue (1 mm). And the pressure on implants placed in the thicker soft tissue would also be greater.[104]

Cyclic loading was performed to simulate mastication. This study carried out centric end loading and slightly rotational posterior movement occurred when the overdentures were posteriorly loaded. A survey revealed that the average number of chewing cycles is about 800,000 per year.[99] The retention values of the attachments were recorded at 0, 100,000, 200,000, 500,000, 700,000 and 1,000,000 cyclic loading cycles, this cycling interval equivalent to average number of chewing cycles in 0, 1.5, 3, 7.5, 10.5 and 15 months, respectively.

In this study, two-parallel implants were tested at 0 degree. In clinical situation, limitations in implant placement which include location, quality and amount of bone, position of nerves and floor of sinus and dentist's experience may influence the degree of implant angulation. Previous studies found that implant angulations influence retention force after applying insertion-removal cycles on the Locator attachment system.[77, 78] In non-parallel implants, there is excessive undercut area in one side, consequently increase area of frictional contact. Thus, the results of this study may not related to non-parallel implants.

According to the study of Abi Nader et al, simulated mastication did not influence the retention of Nobel Biocare ball-socket attachments. Nevertheless, Locator attachments suffered a loss of approximately 60% of retention at 300,000 cycles, which was greater than this study (approximately 6%). Difference in the results may be due to different in experimental setting. In this study, the test was performed in 37 ºC distilled water, not in dry condition as their test. They concluded that simulated mastication resulted in slight wear of the ball attachment tested, which did not influence significantly its retention force. However, simulated mastication caused alterations of Locator attachment's nylon components and consequently decreased the retention force. The mastication was a major factor associated with maintenance needs for the Locator attachment system.[76] Other studies found loss of retention ranging from 30 to 80% for the Locator attachment system following repeated insertion removal cycles.[5, 58, 77]

The second aim of this study was to examine the effect of thermocycling and type of attachment on the retention of two-type attachment systems (ball and Locator). Statistical analysis revealed significant differences of the two main factors; thermocycling and types of attachment. Therefore, the null hypothesis was rejected.

The results showed that the retention of pink Locator attachments was greater than yellow clix insert ball attachments before and after thermocycling. The retention of yellow clix insert ball attachments was not affected by thermocycling. The structure of ball attachment is spherical shape, which present retention around a ball-shaped portion. And the component of female clix insert ball attachment consists of plastic, a polyoxymetylene copolymer, it is abrasive resistance, high heat resistance, and low water absorption, It did not uptake water with no alteration of form or shape.

In contrast, thermocycling had an effect on the retention of Locator attachments, the mean retention values increased significantly after 5,000 and 10,000 cycles. The component of Locator attachment consists of nylon. Changes of temperature may affect the mechanical property and bond strength of nylon to the abutment. Nylon has good abrasive resistance and self-lubricating properties, difficult to wear and tear, therefore no retention loss was found. Locator attachment has outer and inner ring peripheries, which is the main areas of frictional contact, thus providing wider contact surface than ball attachment. Every 1% moisture increase in nylon may result in 0.2 to 0.3% increase in its dimension.[105] And nylon has a strong affinity to uptake water.[106] Upon water uptake, it enlarged, the outer and inner ring frictional contact increased, consequently increased the retention of Locator attachments tested with this system.

In the present study, the attachments were artificially aged using thermocycling to simulate thermal variations of the oral cavity at 5,000 and 10,000 cycles, equivalent to 6 months and 1 year of clinical use, respectively.[107] Al-Ghafli et al revealed that implant angulations contribute significantly to the rate of retention loss of the implant attachment system.[78] This study intended to investigate the effect of temperature changes on the retention of attachments, therefore one implant was selected.

An estimate of 20 N of retention force is probably sufficient for mandibular two-implant overdentures.[102] After 10,000 thermocycling cycles, equivalent to 1 year of clinical use, the mean retention values of yellow clix insert ball and pink Locator attachments were still sufficient for retaining mandibular two-implant overdentures.

In clinical situation, patients have to remove their dentures to clean after meals and before going to bed, an estimation of insertion and removal frequency is 4 times per day,[108] leading to abrasive wear and tear of attachment components over time, which may sufficient to alter retention forces. Nevertheless, insertion-removal, implant angulation and mastication were thought to have caused wear change or deformation of the attachment's components, resulted in eventual loss of retention.

It was reported in a 5-year prospective study that 77 percent of the complication or repair events concerning implant overdentures involved the activation or replacement of the matrix in the prosthesis.[109] Sixty-eight percent of patients in another prospective study required prosthodontic maintenance during the first year of service. Seventy-seven percent of the separate overall prosthodontic maintenance events required activating or replacing the matrices of the unsplinted attachments.[110] However, frequency of matrix replacement was reported as being difficult to predict because of the variability of clinical situations and on whether the decision was made by the patient or the prosthodontist.[111]

In this study, the experiment was divided into two parts to investigate limited and specific mechanical conditions. Nevertheless, the nature of overdenture functioning in complex environment of the oral cavity was difficult to replicate in a laboratory setting. Therefore, this in vitro protocol may not possess adequate clinical relevance. In clinical situation there are many factors such as insertion and removal, implant angulation, implant number, attachment material and design, mastication, parafunction, saliva and artificial substitutes, denture cleaning solutions and food particles. Combination of these factors could also influence the retention of overdentures. However, the result of this study can confirm that if the 2 implants retained overdenture are placed parallel, the loss of retention will hardly take place within 15 months of clinical use.

CHAPTER VI

CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

1. The retention of pink Locator attachments was greater than yellow clix insert ball attachments before and after cyclic loading (p<0.05).

2. The retention of pink Locator attachments was greater than yellow clix insert ball attachments before and after thermocycling (p<0.05).

3. The retention of yellow clix insert ball attachments significantly decreased at 700,000 and 1,000,000 cyclic loading cycles (p<0.05).

4. The retention of pink Locator attachments significantly decreased after 100,000 and 1,000,000 cyclic loading cycles (p<0.05).

5. The retention of yellow clix insert ball attachments was not affected by thermocycling (p<0.05).

6. The retention of pink Locator attachments increased after 5000 thermocycling cycles (p<0.05).

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APPENDIX

Two Way Repeated Measures ANOVA (Two Factor Repetition)

Dependent Variable: retetion
Normality Test: Failed (P < 0.050)
Equal Variance Test: Passed (P = 0.206)

Source of Variation	DF	SS	MS	F	P
subject	5	41.087	8.217		
time	5	158.733	31.747	4.505	0.005
time x subject	25	176.165	7.047		
type	1	6155.321	6155.321	75.968	<0.001
type x subject	5	405.129	81.026		
time x type	5	41.629	8.326	1.210	0.333
Residual	25	172.013	6.881		
Total	71	7150.077	100.705		

Least square means for time :

Group	Mean
0.000	27.681
100000.000	23.772
200000.000	24.809
500000.000	24.137
700000.000	24.165
1000000.000	22.987

Std Err of LS Mean = 0.766

Least square means for type :

Group	Mean
1.000	33.838
2.000	15.346

Std Err of LS Mean = 1.500

Least square means for time x type :

Group	Mean
0.000 x 1.000	36.538
0.000 x 2.000	18.823
100000.000 x 1.000	31.788
100000.000 x 2.000	15.755
200000.000 x 1.000	34.820
200000.000 x 2.000	14.798
500000.000 x 1.000	33.742

500000.000 x 2.000	14.532
700000.000 x 1.000	34.355
700000.000 x 2.000	13.975
1000000.000 x 1.000	31.783
1000000.000 x 2.000	14.190

Std Err of LS Mean = 1.071

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparisons for factor: **time**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.050**
0.000 vs. 1000000.000	4.694	6	6.126	0.003	Yes
0.000 vs. 100000.000	3.909	6	5.101	0.015	Yes
0.000 vs. 500000.000	3.544	6	4.625	0.033	Yes
0.000 vs. 700000.000	3.516	6	4.588	0.035	Yes
0.000 vs. 200000.000	2.872	6	3.747	0.122	No
200000.000 vs. 1000000.000	1.822	6	2.378	0.556	No
200000.000 vs. 100000.000	1.037	6	1.354	0.927	Do Not Test
200000.000 vs. 500000.000	0.672	6	0.878	0.988	Do Not Test
200000.000 vs. 700000.000	0.644	6	0.841	0.991	Do Not Test
700000.000 vs. 1000000.000	1.178	6	1.538	0.882	Do Not Test
700000.000 vs. 100000.000	0.393	6	0.513	0.999	Do Not Test
700000.000 vs. 500000.000	0.0283	6	0.0370	1.000	Do Not Test
500000.000 vs. 1000000.000	1.150	6	1.501	0.892	Do Not Test
500000.000 vs. 100000.000	0.365	6	0.476	0.999	Do Not Test
100000.000 vs. 1000000.000	0.785	6	1.024	0.977	Do Not Test

Comparisons for factor: **type**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.050**
1.000 vs. 2.000	18.492	2	12.326	<0.001	Yes

Comparisons for factor: **type within 0**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.05**
1.000 vs. 2.000	17.715	2	9.893	<0.001	Yes

Comparisons for factor: **type within 100000**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.05**
1.000 vs. 2.000	16.033	2	8.954	<0.001	Yes

Comparisons for factor: **type within 200000**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.05**
1.000 vs. 2.000	20.022	2	11.181	<0.001	Yes

Comparisons for factor: **type within 500000**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.05**
1.000 vs. 2.000	19.210	2	10.728	<0.001	Yes

Comparisons for factor: **type within 700000**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.05**
1.000 vs. 2.000	20.380	2	11.381	<0.001	Yes

Comparisons for factor: **type within 1e+006**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.05**
1.000 vs. 2.000	17.593	2	9.825	<0.001	Yes

Comparisons for factor: **time within 1**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.05**
0.000 vs. 1000000.000	4.755	6	4.414	0.034	Yes
0.000 vs. 100000.000	4.750	6	4.409	0.034	Yes
0.000 vs. 500000.000	2.797	6	2.596	0.453	No
0.000 vs. 700000.000	2.183	6	2.027	0.707	Do Not Test
0.000 vs. 200000.000	1.718	6	1.595	0.868	Do Not Test
200000.000 vs. 1000000.000	3.037	6	2.819	0.361	No
200000.000 vs. 100000.000	3.032	6	2.814	0.363	Do Not Test
200000.000 vs. 500000.000	1.078	6	1.001	0.980	Do Not Test
200000.000 vs. 700000.000	0.465	6	0.432	1.000	Do Not Test
700000.000 vs. 1000000.000	2.572	6	2.387	0.546	Do Not Test
700000.000 vs. 100000.000	2.567	6	2.382	0.548	Do Not Test
700000.000 vs. 500000.000	0.613	6	0.569	0.999	Do Not Test
500000.000 vs. 1000000.000	1.958	6	1.818	0.792	Do Not Test
500000.000 vs. 100000.000	1.953	6	1.813	0.793	Do Not Test
100000.000 vs. 1000000.000	0.00500	6	0.00464	1.000	Do Not Test

Comparisons for factor: **time within 2**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.05**
0.000 vs. 700000.000	4.848	6	4.500	0.029	Yes
0.000 vs. 1000000.000	4.633	6	4.301	0.041	Yes
0.000 vs. 500000.000	4.292	6	3.984	0.071	No
0.000 vs. 200000.000	4.025	6	3.736	0.106	Do Not Test
0.000 vs. 100000.000	3.068	6	2.848	0.349	Do Not Test

100000.000 vs. 700000.000	1.780	6	1.652	0.850	No
100000.000 vs. 1000000.000	1.565	6	1.453	0.907	Do Not Test
100000.000 vs. 500000.000	1.223	6	1.136	0.966	Do Not Test
100000.000 vs. 200000.000	0.957	6	0.888	0.988	Do Not Test
200000.000 vs. 700000.000	0.823	6	0.764	0.994	Do Not Test
200000.000 vs. 1000000.000	0.608	6	0.565	0.999	Do Not Test
200000.000 vs. 500000.000	0.267	6	0.248	1.000	Do Not Test
500000.000 vs. 700000.000	0.557	6	0.517	0.999	Do Not Test
500000.000 vs. 1000000.000	0.342	6	0.317	1.000	Do Not Test
1000000.000 vs. 700000.000	0.215	6	0.200	1.000	Do Not Test

Two Way Repeated Measures ANOVA (Two Factor Repetition)

Normality Test: **Failed (P < 0.050)**
Equal Variance Test: **Passed (P = 0.640)**

Source of Variation	DF	SS	MS	F	P
subject	9	92.760	10.307		
cycle	2	346.666	173.333	59.576	<0.001
cycle x subject	18	52.370	2.909		
type	1	1998.370	1998.370	274.254	<0.001
type x subject	9	65.579	7.287		
cycle x type	2	462.147	231.073	121.162	<0.001
Residual	18	34.329	1.907		
Total	59	3052.220	51.733		

Least square means for **cycle** :

Group	**Mean**
0.000	14.738
5000.000	20.211
10000.000	19.353

Std Err of LS Mean = 0.381

Least square means for **type** :

Group	**Mean**
1.000	23.872
2.000	12.329

Std Err of LS Mean = 0.493

Least square means for **cycle x type** :

Group	**Mean**
0.000 x 1.000	16.584
0.000 x 2.000	12.891
5000.000 x 1.000	27.987
5000.000 x 2.000	12.435
10000.000 x 1.000	27.044
10000.000 x 2.000	11.662

Std Err of LS Mean = 0.437

All Pairwise Multiple Comparison Procedures (Tukey Test):

Comparisons for factor: **cycle**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.050**
5000.000 vs. 0.000	5.473	3	14.351	<0.001	Yes
5000.000 vs. 10000.000	0.858	3	2.248	0.276	No
10000.000 vs. 0.000	4.616	3	12.102	<0.001	Yes

Comparisons for factor: **type**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.050**
1.000 vs. 2.000	11.542	2	23.420	<0.001	Yes

Comparisons for factor: **type within 0**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.05**
1.000 vs. 2.000	3.693	2	6.071	<0.001	Yes

Comparisons for factor: **type within 5000**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.05**
1.000 vs. 2.000	15.552	2	25.566	<0.001	Yes

Comparisons for factor: **type within 10000**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.05**
1.000 vs. 2.000	15.382	2	25.287	<0.001	Yes

Comparisons for factor: **cycle within 1**

Comparison	**Diff of Means**	**p**	**q**	**P**	**P<0.05**
5000.000 vs. 0.000	11.403	3	23.236	<0.001	Yes
5000.000 vs. 10000.000	0.942	3	1.920	0.374	No
10000.000 vs. 0.000	10.460	3	21.315	<0.001	Yes

Comparisons for factor: **cycle within 2**

Comparison	Diff of Means	p	q	P	P<0.05
0.000 vs. 10000.000	1.229	3	2.503	0.195	No
0.000 vs. 5000.000	0.456	3	0.929	0.790	Do Not Test
5000.000 vs. 10000.000	0.773	3	1.574	0.513	Do Not Test

Friedman Repeated Measures Analysis of Variance on Ranks

Dependent Variable: **retention**
Normality Test: **Passed (P = 0.144)**
Equal Variance Test: **Failed (P < 0.050)**

Group	N	Missing	Median	25%	75%
1.000	10	0	16.293	15.226	17.291
2.000	10	0	13.724	11.930	14.350
3.000	10	0	28.339	27.483	29.053
4.000	10	0	12.467	11.435	13.967
5.000	10	0	27.585	25.800	28.247
6.000	10	0	11.930	11.248	13.127

All Pairwise Multiple Comparison Procedures (Student-Newman-Keuls Method):

Comparison	Diff of Ranks	q	P<0.05
3 vs 6	45.000	7.606	Yes
3 vs 4	34.000	6.800	Yes
3 vs 2	32.000	7.838	Yes
3 vs 1	17.000	5.376	Yes
3 vs 5	4.000	1.789	No
5 vs 6	41.000	8.200	Yes
5 vs 4	30.000	7.348	Yes
5 vs 2	28.000	8.854	Yes
5 vs 1	13.000	5.814	Yes
1 vs 6	28.000	6.859	Yes
1 vs 4	17.000	5.376	Yes
1 vs 2	15.000	6.708	Yes
2 vs 6	13.000	4.111	Yes

2 vs 4	2.000	0.894	No
4 vs 6	11.000	4.919	Yes

NPar Tests

Notes

Output Created		03-ต.ค.-2555, 11 นาฬิกา 54 นาที
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	type, cycle
	N of Rows in Working Data File	60
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each test are based on all cases with valid data for the variable(s) used in that test.
Syntax		NPAR TESTS /K-S(NORMAL)=tension /MISSING ANALYSIS.
Resources	Processor Time	0:00:00.015
	Elapsed Time	0:00:00.016
	Number of Cases Allowed[a]	196608

One-Sample Kolmogorov-Smirnov Test

Type	Cycle			Tension
Locator	0	N		10
		Normal Parameters[a,,b]	Mean	16.5841
			Std. Deviation	1.85915
		Most Extreme Differences	Absolute	.227
			Positive	.227
			Negative	-.119
		Kolmogorov-Smirnov Z		.719
		Asymp. Sig. (2-tailed)		.680
	5000	N		10
		Normal Parameters[a,,b]	Mean	27.9868
			Std. Deviation	2.10936
		Most Extreme Differences	Absolute	.216
			Positive	.115
			Negative	-.216
		Kolmogorov-Smirnov Z		.683
		Asymp. Sig. (2-tailed)		.739
	10000	N		10
		Normal Parameters[a,,b]	Mean	27.0444
			Std. Deviation	2.87927
		Most Extreme Differences	Absolute	.138
			Positive	.138
			Negative	-.134
		Kolmogorov-Smirnov Z		.437
		Asymp. Sig. (2-tailed)		.991

Ball	0	N		10
		Normal Parameters[a,,b]	Mean	12.8909
			Std. Deviation	2.24571
		Most Extreme Differences	Absolute	.223
			Positive	.130
			Negative	-.223
		Kolmogorov-Smirnov Z		.705
		Asymp. Sig. (2-tailed)		.703
	5000	N		10
		Normal Parameters[a,,b]	Mean	12.4350
			Std. Deviation	1.87321
		Most Extreme Differences	Absolute	.128
			Positive	.128
			Negative	-.115
		Kolmogorov-Smirnov Z		.404
		Asymp. Sig. (2-tailed)		.997
	10000	N		10
		Normal Parameters[a,,b]	Mean	11.6624
			Std. Deviation	1.57423
		Most Extreme Differences	Absolute	.196
			Positive	.120
			Negative	-.196
		Kolmogorov-Smirnov Z		.620
		Asymp. Sig. (2-tailed)		.836

Univariate Analysis of Variance

Notes

Output Created		03-ต.ค.-2555, 11 นาฬิกา 55 นาที
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	60
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		UNIANOVA tension BY type cycle /METHOD=SSTYPE(3) /INTERCEPT=INCLUDE /CRITERIA=ALPHA(0.05) /DESIGN=type cycle type*cycle.
Resources	Processor Time	0:00:00.016
	Elapsed Time	0:00:00.016

Between-Subjects Factors

		Value Label	N
type	1	locator	30
	2	ball	30
cycle	1	0	20
	2	5000	20
	3	10000	20

Tests of Between-Subjects Effects

Dependent Variable: tension

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2807.183[a]	5	561.437	123.726	.000
Intercept	19657.903	1	19657.903	4332.106	.000
type	1998.370	1	1998.370	440.390	.000
cycle	346.666	2	173.333	38.198	.000
type * cycle	462.147	2	231.073	50.923	.000
Error	245.037	54	4.538		
Total	22710.124	60			
Corrected Total	3052.220	59			

Oneway

Notes

Output Created		03-ต.ค.-2555, 11 นาฬิกา 58 นาที
Comments		
Input	Active Dataset	DataSet0
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	60
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics for each analysis are based on cases with no missing data for any variable in the analysis.
Syntax		ONEWAY tension BY group /STATISTICS DESCRIPTIVES HOMOGENEITY BROWNFORSYTHE /MISSING ANALYSIS /POSTHOC=TUKEY ALPHA(0.05).
Resources	Processor Time	0:00:00.016
	Elapsed Time	0:00:00.015

Descriptives

tension

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	10	16.5841	1.85915	.58792	15.2541	17.9140	14.39	20.59
2	10	27.9868	2.10936	.66704	26.4779	29.4957	23.03	30.52
3	10	27.0444	2.87927	.91050	24.9847	29.1041	21.06	31.92
4	10	12.8909	2.24571	.71016	11.2845	14.4974	8.93	15.57
5	10	12.4350	1.87321	.59236	11.0950	13.7750	9.50	15.09
6	10	11.6624	1.57423	.49781	10.5363	12.7885	8.54	13.51
Total	60	18.1006	7.19253	.92855	16.2426	19.9586	8.54	31.92

Test of Homogeneity of Variances

Tension

Levene Statistic	df1	df2	Sig.
.620	5	54	.685

ANOVA

tension

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2807.183	5	561.437	123.726	.000
Within Groups	245.037	54	4.538		
Total	3052.220	59			

Robust Tests of Equality of Means

tension

	Statistic[a]	df1	df2	Sig.
Brown-Forsythe	123.726	5	46.214	.000

a. Asymptotically F distributed.

Post Hoc Tests

Multiple Comparisons

Tension

Tukey HSD

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

(I) group	(J) group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1	2	-11.40275*	.95265	.000	-14.2173	-8.5882
	3	-10.46035*	.95265	.000	-13.2749	-7.6458
	4	3.69310*	.95265	.004	.8785	6.5077
	5	4.14905*	.95265	.001	1.3345	6.9636
	6	4.92165*	.95265	.000	2.1071	7.7362
2	1	11.40275*	.95265	.000	8.5882	14.2173
	3	.94240	.95265	.919	-1.8722	3.7570
	4	15.09585*	.95265	.000	12.2813	17.9104
	5	15.55180*	.95265	.000	12.7372	18.3664
	6	16.32440*	.95265	.000	13.5098	19.1390
3	1	10.46035*	.95265	.000	7.6458	13.2749
	2	-.94240	.95265	.919	-3.7570	1.8722
	4	14.15345*	.95265	.000	11.3389	16.9680
	5	14.60940*	.95265	.000	11.7948	17.4240
	6	15.38200*	.95265	.000	12.5674	18.1966
4	1	-3.69310*	.95265	.004	-6.5077	-.8785
	2	-15.09585*	.95265	.000	-17.9104	-12.2813
	3	-14.15345*	.95265	.000	-16.9680	-11.3389
	5	.45595	.95265	.997	-2.3586	3.2705
	6	1.22855	.95265	.789	-1.5860	4.0431
5	1	-4.14905*	.95265	.001	-6.9636	-1.3345
	2	-15.55180*	.95265	.000	-18.3664	-12.7372
	3	-14.60940*	.95265	.000	-17.4240	-11.7948
	4	-.45595	.95265	.997	-3.2705	2.3586
	6	.77260	.95265	.964	-2.0420	3.5872
6	1	-4.92165*	.95265	.000	-7.7362	-2.1071
	2	-16.32440*	.95265	.000	-19.1390	-13.5098
	3	-15.38200*	.95265	.000	-18.1966	-12.5674
	4	-1.22855	.95265	.789	-4.0431	1.5860
	5	-.77260	.95265	.964	-3.5872	2.0420

Homogeneous Subsets

tension

Tukey HSD[a]

group	N	Subset for alpha = 0.05		
		1	2	3
6	10	11.6624		
5	10	12.4350		
4	10	12.8909		
1	10		16.5841	
3	10			27.0444
2	10			27.9868
Sig.		.789	1.000	.919

BIOGRAPHY

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