Retention Values of Locator Attachments Versus Different Implant Angulations

Nancy Dubois
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D.M.D., Université Laval, 1992

A Thesis
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Presented by
Nancy Dubois, D.M.D.

Major Advisor
John R. Agar

Associate Advisor
Geoffrey A. Thompson

Associate Advisor
Jacqueline P. Duncan

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1. BACKGROUND

Introduction

Complete edentulism is a debilitating dental condition affecting millions of individuals. Complete removable prostheses are the most common and widely used treatment modality of rehabilitation for edentulism.

The number of edentulous people increases with age. Caries and periodontal disease being irreversible lead to edentulism when not stabilized. After reviewing literature on surveys and reports conducted between 1985 and 2000 in countries from United Nations, Mojon found that edentulism increases with age especially after 70 years old. He also noted that there are variations between and within countries. For example, between 1985 and 1999, in the 65 to 74 year old group, the edentulous rate varied from 71.5% in Iceland, 22.9% in United States and 0% in Kenya. Based on nationwide telephone survey within United States, for the same age group, between 1995 and 1997, the rate varied from 12% in Hawaii to 44.7% in West Virginia, a range that could not be found in any other countries. Statistics Canada held a Health Promotion Survey in 1990 surveying 14,000 inhabitants and discovered a range varying from 41% in Ontario to 67% in Quebec.

Predisposing factors for edentulism include education, income, economic development and rural versus urban habitats. Overall, the risk of being edentulous is two times higher for a less educated population, a tendency that appears to be decreasing with time, according to Mojon. In general, people with lower income tend to have a higher rate of edentulism. This is likely due to the cost of treatments. Full mouth extraction is
typically the least expensive treatment modality. Government subsidization to dental care may affect the impact of income on edentulism. In countries like Sweden where dental treatment is covered by the government, this factor must be taken into consideration in analyzing data on edentulism.

Edentulism is higher in rural areas than in cities of industrialized countries. This difference has traditionally been attributed to a lower density of dentists in rural areas as compared to cities. But when the density of dentists is plotted against edentulous rate for over 30 countries worldwide, the result is contradictory. A higher edentulous rate will occur with a higher density of dentists. And, throughout the same density of dentists, the range of variations for the rate of edentulism will be wide.

These factors cannot fully describe the edentulism problem. An important role seems to be played by psychosocial and cultural factors.

Health has been related to edentulism. Several reports have described a lower incidence of edentulism in healthy patients. Smoking habits, diabetes, cardiovascular disease, depression and frail elderly adults are more likely to be edentulous.

Few countries have data available to evaluate the decline of edentulism over the past 40 years. Nevertheless, Finland, Sweden, United States, Canada and United Kingdom have reported rates varying between 0.1 to 1.5% declines per year.

Considering the slow rate of decline of edentulism, it appears doubtful that this condition will be completely eradicated in the next 20 years. According to Douglass, who discussed the question: "Will there be a need for complete dentures in the United States in 2020?" the demand for complete removable prostheses will increase for the next 20
years. His reasoning is that the projected aging population will create demands for treatment that will surpass the decline in edentulism.  

The maxillary complete removable prosthesis renders a better service to the patient as far as retention, support and stability compared to the mandibular complete removable prosthesis. The major advantage in the maxilla is the presence of the palate and generally substantial residual alveolar ridge height. Together, these anatomical features provide support and stability for the prosthesis during function. The support area for the mandibular ridge represents 1/3 of that found in the maxilla. The absence of the palate for support is unfavorable. The residual alveolar ridges in the mandible are also important for stability, but the rate of resorption is 4 times greater then in the maxilla. The aging patient gradually experiences a greater decrease in stability of the mandibular complete removable prosthesis as compared to the maxillary prosthesis.

The use of retained roots or implants can improve stability of a complete removable prosthesis and preserve alveolar ridge. They can provide retention if attachments are used to engage a counterpart in an overdenture. The land-mark articles that describe simplified overdenture treatment using retained roots were published in 1969 by Morrow et al and by Lord and Teel. Root retained overdenture is a predictable treatment because it provides extended stability and prevents bone resorption. However, it adds to the treatment cost because it involves elective endodontic treatment. Longitudinal studies evaluating long term prognosis of root retained overdenture were conducted. In one study 44 overdenture patients were followed for 5 years. The authors found that caries ranged from 2.1% to 21% and that 94% of the abutment teeth needed periodontal treatment. They concluded that annual professional oral maintenance is
important. Toolson and Taylor\textsuperscript{10} in a ten year study of 89 patients found that most of the abutments had progressively lost attached tissue, and that patients were at risk of developing caries and losing their abutment teeth unless they had excellent home care with fluoride solutions and professional care.

The era of implantology has revolutionalized dentistry including the overdenture treatment modality. The use of roots to stabilize, support and retain overdenture is now replaced by the use of implants. An approach exempt of disadvantages like caries and periodontal complications. Mericske-Stern, in a comparison of overdentures retained by roots or implants, concluded that the cost-effectiveness of implants of is more favorable than attempting periodontal and endodontic heroic therapy to save few remaining teeth.\textsuperscript{11}

The 2 implants supported mandibular overdenture has been largely investigated. Based on a comprehensive literature reviewed by a panel of experts, the 2002 McGill symposium established the complete mandibular overdenture supported by 2 implants as the new standard of care for edentulism of the mandible.\textsuperscript{12}

The options available for overdentures are the splinted or non splinted attachment systems. A splinted system requires the use of a bar connecting the implants and clips as attachments (Fig. 1). This option is recommended when the implants are not parallel or more than 2 implants are present. The non splinted approach leaves the 2 implants separated and requires the use of stud attachments or magnets. (Fig. 2) This treatment is less technique sensitive, less costly and easier to clean which makes it attractive to both the clinician and patient.
Some studies report that the implants should be placed parallel to each other to maximize retention, minimize premature wear on the attachment system\cite{13,14,15,16} and minimize stress concentration on the implants.\cite{17} Stud attachments have been
recommended for use only when implants are parallel or minimally divergent. A non parallel orientation of the attachment system generates concern regarding incomplete seating of the prosthesis, unpredictable retention or premature wear of the attachment components when the design does not allow the matrix to rotate and pivot around the patrix.18

Clinically, implants will rarely be completely parallel. Despite the use of a surgical guide to orient the implant placement, factors like surgeon skills, patient cooperation, bone morphology and stability of the guide itself can alter the final position of the implants.

The Locator attachment is a non-splinted, stud retained attachment system. According to the manufacturer, this system is able to withstand implant angulation in relation to vertical of up to 20° (40° divergence between 2 implants).19 Studies on the behavior of the Locator attachment system under different implant angulations are absent from the literature.
Review of Previous Studies

Literature about the Locator attachment systems is sparse. Only a few studies have been found. Three of them are from the same authors. In their first study, they 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.

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.

In a third study, 9 attachment systems were evaluated 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 dislodgment after wear simulation was 8.0 N. The 3 studies mentioned simulated a periodontal ligament around cast roots shaped like canines.

Chung et al recorded the peak-load-to-dislodgment and strain at dislodgement for 9 attachment systems including Locator pink and Locator white. 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.
Test Development Rationale

It has been demonstrated that non-parallel implants used to retain mandibular overdenture can be successfully managed, up to a certain extent, with spherical attachments if implant angulation is known and addressed appropriately. Based on scientific studies, maintenance predictability of spherical attachments can be improved. However, scientific evidence about the capability of Locator attachments to maintain retention values for parallel and non-parallel implants configurations is lacking. Clinically, an attachment system that will rapidly lose retention due to fatigue is useless. Therefore, a study about the behavior of an attachment system under a significant number of insertion-removal cycles is indicated. The clinician should be able to base his/her decision in using an attachment system for non-parallel implants on studies independent of manufacturer’s claims. To the author’s knowledge, there are no independent studies that evaluate the retentive values of the Locator system in non-parallel implants configurations.

This study compares the retentive values of the Locator attachment system at different implant angulations in a 2 implants overdenture setting. The results should improve clinician’s knowledge of Locator attachment systems under parallel and non-parallel implants configurations.

A Locator attachment system consists of a matrix and a patrix. The manufacturer refers to female and male components to describe the system. The terms matrix (female) and patrix (male) will be used to describe the system in this study. The matrix is composed of a Locator abutment made of Titanium with a Titanium-nitride coating. It is
inserted into an implant and torqued to 25 Newton centimeter (Ncm) force as prescribed for Astratech implants, with a specific torque wrench.

**Figure 3.** The Locator abutment (matrix) on the right and an Astratech implant on the left.

The patrix is a Locator cap with an interchangeable nylon insert.

**Figure 4.** The metal cap and nylon insert (patrix) (picture courtesy of Astratech us).

The patrix engages the matrix to provide a sufficient retention force to stabilize and retain the overdenture.
Figure 5. Locator attachment system includes a patrix and a matrix.

Clinically, the patrix is embedded in the overdenture and the matrix remains intra-orally (Fig. 6). The patient is able to manually engage and disengage the overdenture.

Figure 6. Matrices are inserted in the implants and patrices are embedded in the overdenture.
The manufacturer offers 5 interchangeable nylons (Fig. 7) to be used according to the clinical situation.

![Five different nylons recommended for the Locator attachment system names by their color, clear, pink, blue, green and red.](image)

**Figure 7.** Five different nylons recommended for the Locator attachment system names by their color, clear, pink, blue, green and red.

The clear, pink or blue nylons are recommended for angulations varying from $0^\circ$ to $10^\circ$. Their retention capabilities are described to be respectively 2268, 1361 and 680 grams. The green and red nylons are recommended for implant angulations varying from $10^\circ$ to $20^\circ$. Their respective retention capabilities are in a range of 1361-1418 and 680 grams.

Unlike the green and red nylons, the clear, pink and blue nylons present an internal extension engaging into a socket on the top of the Locator abutment (Fig. 8). The retention obtained from the internal and external features of the abutment is called *Dual retention*. The extension has been removed from the green and red nylon inserts to reduce the additional retention created by the divergence of the implants.
Figure 8. Cross sectional view of the implant/abutment/Locator attachment system assembly showing the pink and green nylon inserts.
There are 5 main advantages to the Locator system advertised by the manufacturer. 19

1) It has a low vertical height compared to other systems allowing the clinician to use it in areas of restricted vertical space. It is important to consider that its diameter is larger than most other attachment systems which can represent a limitation.

Figure 9. Locator attachment system height (5th from the left) compared to other common attachment systems. Upper picture is a view from the side, and the lower picture is a view from the top (pictures courtesy of Dr. John Agar).
2) The self-aligning design allows for the patrix and the matrix to attach together without precise alignment, which makes the connection easier to execute by the patient.

Figure 10. The Locator attachment system (5th from left) allows the patrix and matrix to get aligned easily (pictures courtesy of Dr. John Agar).
3) The *Dual Retention* is patented and has been incorporated in the clear, pink and blue nylon inserts to increase the retention surface area ensuring long lasting retention life in the $0^\circ$ to $10^\circ$ situation.

![Figure 11. Dual retention feature inside of the clear, pink and blue nylons (picture courtesy of Astratech us).](image)

4) The rotational pivoting action allows a resilient connection for the prosthesis. This feature reduces the amount of retention loss. The nylon remains in contact with the abutment while the metal cap moves over the nylons.

![Figure 12. Rotational pivoting action of the patrix over the nylon and the matrix.](image)
Finally, they can be used in non-parallel implant situations. The clear, pink and blue can compensate for up to 10° of divergence from vertical (20° between implants) while the green and red inserts can be used for up to 20° of divergence from vertical (40° between implants). The internal extension is absent from the green and red insert to compensate for the angulation.

![Figure 13. Absence of the dual retention feature inside of the red and green nylons (picture courtesy of Astratech us).](image.png)

In this study, the pink and the green nylons will be used because they are described as having retention capabilities within the same range. They are respectively recommended for 0°-10° and 10°-20° divergence from vertical. Since the manufacturer adapted the Locator nylon inserts to manage divergent implants, the retention should be similar when the pink and the green nylons are used as recommended.

In a situation where the 2 implants are divergent, the patrix will still be aligned with the matrix but the path of insertion-removal will be directed by the overdenture. The attachments will be detached from the abutment at an angle different than with parallel implants, creating friction at specific sites on the nylons and abutment. The manufacturer claims the design of the insert against the metal cap compensates for lack of parallelism. Wear is expected to occur if the attachment design does not effectively compensate for non parallel components with multiple attachments after a certain number of insertion-removal cycles of the overdenture (Fig. 14).
Figure 14. In a divergent implant situation, the path of insertion-removal could potentially generate wear at the distal portion of the nylon (circled area).
2. GENERAL AND SPECIFIC OBJECTIVES

General objective

The objective of this study is to evaluate the retention values of the Locator attachment system at different implant angulations in a simulated 2 implants overdenture situation over a period equivalent to 1 year of insertion-removal, 3 times a day (1200 cycles).

Specific objectives

The specific objectives are to:

1) Evaluate the impact of implant angulation on initial retention values.
2) Evaluate the impact of implant angulation on loss of retention.
3) Evaluate the impact of type of nylons on initial retention values.
4) Evaluate the impact of type of nylons on loss of retention values.
5) Evaluate impact of 1200 cycles on the condition of the abutments and nylons.
3. HYPOTHESIS

The prediction is that there will be a decrease in retention values during the 1200 cycles for all groups and that there will be a more accentuated decrease in retention value as the angulation between the implants increases.

Null Hypothesis

1) Implant angulation does not affect retention value variations.

2) Implant angulation does not affect initial retention values.

3) 1200 cycles does not affect initial retention values.
4. MATERIAL AND METHODS

Testing assembly

A custom holding device was used to firmly hold the patrices and matrices while an axial motion pushed the attachment system together and pulled it apart (Fig. 16). It was designed and machined by Material Testing Technology Co. (MTT, Palatine, IL). The device consisted of two separate holding parts (Fig. 16-20). The upper portion held 2 metal tubes in which the Locator cap-nylon (patrices) were press fitted (Fig. 18). The lower portion held two acrylic resin tubes in which the implant-abutments (matrices) were torqued. Each part had the capability to modify the angulations of the attachment system from $0^\circ$ to $10^\circ$ to $20^\circ$. The holding device was designed to be attached to the 858 Mini Bionix II Test System (MTS system corporation, Chicago, IL) a hydraulic testing machine engineered to generate axial motions (Fig. 15).
Figure 15. 858 Mini Bionix II testing device (drawings from MTS co. brochure).

Figure 16. Drawings illustrating the holding device with the 3 implant angulations possibilities (drawings by Material Testing Technology Co., IL).
Figure 17. Front view of the upper part of the holding device.

Figure 18. Bottom view of the upper holding device showing the receptacle for the metal tubes in which the cap will be press fitted.
The caps were press fitted in the metal tubes using a vice. The size of the holes was precisely engineered to avoid any deformation of the caps. The use of the vice in combination with the precise size of the holes allowed the caps to be precisely fitted in all the metal tubes.

![Image of pink nylons press fitted in the caps.]

**Figure 19.** The pink nylons press fitted in the caps.

The metal tubes were designed to be of identical dimension. Three different pairs were prepared for the 3 implants angulations.
**Figure 20.** Metal tubes for 0°, 10° and 20° angulations.

**Figure 21.** Lower part of holding device.

The lower portion was designed to contain all the implant angulations. The center of rotation was the center of the abutment and was held at a constant distance of 22mm throughout the change of angulations.
Figure 22. The implant was torqued in the acrylic resin tube.

Figure 23. Holding device.
Experimental design

The 858 Mini Bionix II axial servo hydraulic test system was used to perform axial push and pull motions of the patrices against the matrices torqued in Astratech implants (4x11mm ST). The set up consisted of:

a. 858 Mini Bionix axial servo hydraulic machine

b. Load cell unit

c. Holding device with the Locator attachment system

d. Computer and Software to collect and analysis data

Figure 24. Testing assembly.

The axial movement was performed under loads with a standard displacement of 50 mm/sec. The Load cell unit acted as a guardian, preventing the machine from exerting pushing forces of more than 250 N.
The 858 Mini Bionix II hydraulic system performed a pushing and pulling vertical motion. Each sample was tested for 1200 cycles. A few studies have reported maintenance requirements for mandibular overdenture supported by 2 implants to be higher during the first year post insertion.\textsuperscript{25-29} These studies included splinted and non-splinted attachment systems but none of them included the Locator attachment system. In the absence of clinical follow-up specifically reporting on the Locator attachment system, the decision was made to proceed with the equivalent of 1 year of insertion-removal of the overdenture, 3 times a day. The calculation comes up to approximately 1200 cycles.

The peak-load-to-dislodgement values were recorded for every cycle. A pause of 2 seconds after pulling and pushing occurred to allow for the nylon inserts to recover, to a certain extent. A load cell unit controlled the motion and registered the values in N.

Overall, 8 abutments (2 new ones for each group), 2 Locator caps and 2 Astratech implants were used. They were verified for signs of wear between each specimen and none were detected throughout the testing. A total of 120 Nylons were tested (1 pair for each specimen).

The groups were divided in 0 degree angulation with pink insert (0P), 10 degrees with pink insert (10P), 10 degrees with green insert (10 G) and 20 degrees with green insert (20G). Each group was composed of 15 specimens. The following table is a description of the groups.
<table>
<thead>
<tr>
<th>Group</th>
<th>Specimens</th>
<th>Angulation</th>
<th>Nylon type</th>
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<tr>
<td>0P</td>
<td>15</td>
<td>0°</td>
<td>Pink</td>
</tr>
<tr>
<td>10P</td>
<td>15</td>
<td>10°</td>
<td>Pink</td>
</tr>
<tr>
<td>10G</td>
<td>15</td>
<td>10°</td>
<td>Green</td>
</tr>
<tr>
<td>20G</td>
<td>15</td>
<td>20°</td>
<td>Green</td>
</tr>
</tbody>
</table>

**Table 1.** Groups description, P: Pink, G: Green, 0: 0 Degree, 10: 10 Degrees, 20: 20 Degrees

The nylons were verified visually before and after testing to ensure integrity. Photographs of all the nylons were taken for comparison after testing.

The abutments were visually inspected for manufacturing defects, and the diameter was measured at 3 different locations with a micrometer (Electronic Micrometer, L.S. Starrett Co, Athol, MA) for abutment to verify the consistency in size.

Scanning electron microscopy (SEM) was used to observe the patterns of wear in the nylons and on the abutments.

Testing was performed at the Army dental and Trauma Research Detachment, Great Lakes, Illinois under the supervision of Colonel J Thompson, Chief of Dental Biomaterials Branch, Army division.
5. STASTICAL ANALYSIS

Data Collection

As the testing was performed, the data was collected and plotted on a histogram to monitor the course of events (Fig. 25). The cycle began when the attachment system was connected. At this point, a pause of 1 second was observed. The cycle started at 1 second pause and remained in pause for an additional second until an axial pulling motion was initiated. The pulling motion occurred for a distance sufficient to separate the attachment system. During the pulling motion, the peak-load-to-dislodgement value was recorded as a positive value and represents point 3 on the figure below. The pulling motion lasted until point 4. At this point, another pause of 2 seconds occurred as the attachment system was completely apart. Once the pausing time elapsed, a pushing motion was initiated (5) and the peak-load-to-engagement value (6) was recorded as a negative value by the software. After this stage, the system remained engaged for a total of 2 seconds but, only 1 second was part of the finishing cycle (7).
1) Pause
2) Pulling motion
3) Peak-load-to-dislodgment value
4) Pause
5)Pushing motion
6) Peak-load-to-engagement value
7) Pause

**Figure 25.** Histogram illustrating a description of 1 cycle with an explanatory legend.
The raw data was presented by segments with axial displacement, axial force and time of occurrence (Table 2). The axial force was represented by a positive and negative value in N. The positive axial force was the peak-load-to-dislodgement value and the negative force represented the peak-load-to-engagement value, the pushing force.

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<thead>
<tr>
<th>Segments</th>
<th>Time</th>
<th>Displacement</th>
<th>Axial Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>38.73096</td>
<td>0.333337</td>
<td>48.07803</td>
</tr>
<tr>
<td>2</td>
<td>41.1543</td>
<td>0.463291</td>
<td>-42.1937</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Segments</th>
<th>Time</th>
<th>Displacement</th>
<th>Axial Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>43.15894</td>
<td>0.357854</td>
<td>37.94659</td>
</tr>
<tr>
<td>7</td>
<td>45.60693</td>
<td>0.428482</td>
<td>-37.8848</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Segments</th>
<th>Time</th>
<th>Displacement</th>
<th>Axial Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>47.55103</td>
<td>0.347087</td>
<td>35.37046</td>
</tr>
<tr>
<td>11</td>
<td>50.01978</td>
<td>0.429785</td>
<td>-36.1031</td>
</tr>
</tbody>
</table>

Table 2. Example of raw data collection with peak load values highlighted in yellow

The peak-load-to-dislodgment values (pulling motion) were recorded for the 1200 cycles. The data reflect the amount of force needed to separate the attachment system. The peak-load-to-dislodgment values were extracted for analysis at cycles 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 50, 75, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100 and
1200 for each specimen. The data were extracted at a higher frequency for the first 100 cycles. A previous study on fatigue testing with Locator attachment system \(^{21}\) reported an important loss of retention within the first 100 cycles. The same situation was expected in this study. In order to better qualify the behavior, an extended number of data were extracted between cycles 1 and 100. Means by cycles were calculated for each group and a graph illustrating the general behavior was produced.

**Statistical analysis**

Data were analyzed using the SPSS version 15 for Windows program (SPSS Inc., Chicago, IL, USA). The following specific comparisons were planned for statistical analysis in the protocol.

**Comparison of initial retention**

1) Compare groups 0P and 10P to groups 10G and 20G for the influence of the implant angulation

2) Compare groups 10P and 10G for the influence of the nylon

3) Compare all the groups

**Comparison of retention value changes after 1200 cycles**

1) Compare groups 0P and 10P and Group 10G and 20G for the influence of the implant angulations

2) Compare group 10P and 10G for the influence of the nylon insert

3) Compare all Groups
Comparison of 1200 cycles and 20 cycles for significance of change

For each group individually, compare the difference in retention value between 1200 and 20 cycles to determine the significance of the change after cycling.
6. RESULTS

Overall results

Means were calculated for each group at every 100 cycles. A graph was obtained to evaluate the behavior of each group and determine if comparisons were valuable. The following graph is a representation of the overall performance of the 4 groups.

**Figure 26.** Graph illustrating Peak-load-to-dislodgement versus Cycles for the 4 groups (0P= 0° with pink insert, 10P= 10° with pink insert, 10G= 10° with green insert and 20G= 20° with green insert) between cycles 1 and 1200.
Initial retention values

The next step of the analysis was to establish a realistic initial retention value. In a study by Rutkunas et al in 2005, the retention values indicated a substantial decrease within the first 100 cycles of a 2000 cycles analysis. To explore this behavior, data were extracted more frequently between cycles 1 and 100 for the final data analysis. The graph in Figure 27 illustrates a substantial loss of retention value in the first 100 cycles. The data were further explored to find at which point the decrease in retention value occurred. The behavior of the Locator attachment system for the first 30 cycles was plotted at a 5 cycle interval. According to the graph in Figure 28, cycle 20 appears to be the point at which the retention stabilizes. This value was selected as the initial retention value. Clinically, at the overdenture delivery appointment, the overdenture is probably inserted and removed by the clinician and patient approximately 20 times for adjustments and patient education. Thus when the patient is sent home, it can be assumed that the overdenture has been submitted to sufficient cycling to reach stability.
Figure 27. Graph illustrating Peak-load-to-dislodgement values versus Cycles for the 4 groups between cycles 1 and 100.
Figure 28. Graph illustrating Peak-load-to-dislodgement values versus cycles for the 4 groups between cycles 1 and 30.
Changes in retention values

The retention values at 1200 cycles were necessary to calculate the changes in retention. The following table indicates the initial and final mean retention values, the change in retention value between initial and final with a standard deviation (sd), and the % change in retention values.

<table>
<thead>
<tr>
<th>Group</th>
<th>Initial mean retention value 20 cycles (N)</th>
<th>Final mean retention value 1200 cycles (N)</th>
<th>Change in retention value ±sd (N)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>0P</td>
<td>40.2</td>
<td>34.8</td>
<td>-5.4 ±10.9</td>
<td>-13%</td>
</tr>
<tr>
<td>10P</td>
<td>37.2</td>
<td>31.1</td>
<td>-6.1±8.9</td>
<td>-16%</td>
</tr>
<tr>
<td>10G</td>
<td>71.3</td>
<td>63.5</td>
<td>-7.8 ±15.8</td>
<td>-11%</td>
</tr>
<tr>
<td>20G</td>
<td>51.0</td>
<td>52.7</td>
<td>+1.7 ±13.6</td>
<td>+3%</td>
</tr>
</tbody>
</table>

Table 3. Change in retention value at 1200 cycles.
Figure 29. Percentage change in retention value between 20 and 1200 cycles versus groups.

Sample distribution

The sample distribution was used to identify the most appropriate tests to perform. The sample distributions were established for each group at 20 cycles, 1200 cycles and for change in retention value. The mean and median were also calculated to evaluate their proximity. Using frequency analysis in the SPSS program, the following charts were obtained.
At 20 cycles, the sample distributions were different from one group to another and presented asymmetrical shapes with substantial deviation from normality. (Fig. 30) Therefore, although attempts to transform data would not be expected to be effective and were in fact not, the variances were not statistically significantly different. The ANOVA and t-test would not be appropriate tests given the data structure.
At 1200 cycles, the sample distributions were different from one group to another and also presented asymmetrical shapes which again deviated from normality. However, for these data, the variances were statistically significantly different which made the sample distribution even more different. The ANOVA and t-test were therefore again not appropriate tests. The same situation occurred with the change in retention values.

Given that the data could not be acceptably transformed to use an ANOVA or t-test a non-parametric evaluation was performed. The Kruskall-Wallis test and Mann-Whitney U test were used.

An alpha level of 0.01 (\(\alpha = 0.01\)) was selected as an appropriate probability level given the conduction of multiple comparisons.
**Overall results**

The mean, median and sd were calculated for the initial retention values, final retentions value and change in retention values for all the specimen combined in each groups.

<table>
<thead>
<tr>
<th>Group</th>
<th>Initial retention values (cycle 20)</th>
<th>Final retention values (cycle 1200)</th>
<th>Change in retention values (1200-20 cycles)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (N)</td>
<td>Median (N)</td>
<td>sd</td>
</tr>
<tr>
<td>OP</td>
<td>40.1</td>
<td>36.4 ±12.2</td>
<td></td>
</tr>
<tr>
<td>1OP</td>
<td>37.1</td>
<td>37.0 ±8.8</td>
<td></td>
</tr>
<tr>
<td>1OG</td>
<td>71.3</td>
<td>68.0 ±7.6</td>
<td></td>
</tr>
<tr>
<td>20G</td>
<td>51.0</td>
<td>52.2 ±8.5</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Mean, median and sd for each group at initial value, final and change in retention values.

**Comparisons**

The specific objectives and null hypothesis of this research were verified using specific comparisons. The Mann-Whitney-Wilcoxon tests and Kruskall-Wallis tests were used to make and analysis of comparisons. The results for each series of comparisons are presented in table 6, 7 and 9.

**Comparisons of initial retention values**

The first series of comparisons were made at cycles 20, the initial retention value, to explore the influence of angulation and type of nylon. Table 6 indicates the results of
the comparisons. The p. values are indicated and they were related to a confidence level of $\alpha = 0.01$.

<table>
<thead>
<tr>
<th>Group comparisons</th>
<th>p. value</th>
<th>Statistical significance at $p &lt; 0.01$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0P compared to 10P</td>
<td>0.787</td>
<td>Not different</td>
</tr>
<tr>
<td>10P compared to 10G</td>
<td>0.000</td>
<td>Different</td>
</tr>
<tr>
<td>10G compared to 20G</td>
<td>0.000</td>
<td>Different</td>
</tr>
<tr>
<td>10P compared to 20G</td>
<td>0.001</td>
<td>Different</td>
</tr>
</tbody>
</table>

**Table 5.** Statistical significance of comparisons of initial retention values between groups at 20 cycles

1) Compare groups 0P and 10P to groups 10G and 20G for the influence of the implant angulation.

*Result:* Group 0P and 10P were not statistically different, 10G and 20G were statistically different but 0P and 10P were different then 10G and 20G. The implant angulation had an influence on the initial retention value of the green nylon but not on the pink nylon insert.

2) Compare groups 10P and 10G for the influence of the nylon.

*Result:* Groups 10P and 10G were statistically different. The initial retention value for group 2 was 37.1 N and for group 3 it was 71.3 N. For the same angulation, the green nylon insert exhibited more retention value than the pink nylon insert.

3) Compare all the groups.

*Result:* This was done indirectly at point 1) and 2) and the conclusions were drawn.
Comparison of retention value changes after 1200 cycles

The second series of comparisons related to the change in retention values at 1200 cycles. The mean change was used and was calculated using mean values at 1200 cycles minus the mean values at 20 cycles. Table 7 indicates the results at a p. value of <0.01.

<table>
<thead>
<tr>
<th>Group comparisons</th>
<th>p. value</th>
<th>Statistical significance at p &lt; 0.01</th>
</tr>
</thead>
<tbody>
<tr>
<td>0P compared to 10P</td>
<td>0.604</td>
<td>Not different</td>
</tr>
<tr>
<td>10P compared to 10G</td>
<td>0.724</td>
<td>Not different</td>
</tr>
<tr>
<td>10G compared to 20G</td>
<td>0.085</td>
<td>Not different</td>
</tr>
<tr>
<td>10P compared to 20G</td>
<td>0.580</td>
<td>Not different</td>
</tr>
</tbody>
</table>

Table 6. Statistical significance of comparisons of retention value changes between groups after 1200 cycles.

1) Compare groups 0P and 10P and Group 10G and 20G for the influence of the implant angulations.

*Result:* All the groups were not statistically different. The implant angulation did not have an impact on change in retention values.

2) Compare group 10P and 10G for the influence of the nylon insert.

*Result:* All the groups were not statistically different. The nylon insert did not have an impact on change in retention values.
3) Compare all Groups.

*Result:* Because all the groups were not statistically significant different the following conclusion can be drawn: The overall groups exhibited a change in retention value after 1200 cycles. Hence, a calculation of a mean % change of retention for the overall attachment system behavior was possible.

<table>
<thead>
<tr>
<th>All Groups combined</th>
<th>Initial mean retention value 20 cycles ±sd (N)</th>
<th>Final mean retention value 1200 cycles ±sd (N)</th>
<th>Change in retention value ±sd (N)</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>49.9± 9.3</td>
<td>45.5±8.6</td>
<td>-4.4±12.3</td>
<td>- 9%</td>
</tr>
</tbody>
</table>

**Table 7.** Overall initial, final and change in retention value and sd for all groups combined.

However, the next question arises from this calculation: Was the change in retention values statistically significant between 1200 and 20 cycles? The following comparisons were made to answer this question.

**Comparison of 1200 cycles and 20 cycles for significance of change**

The last series of comparisons was used to determine if the retention values were statistically different or not between 1200 and 20 cycles. The analysis compared 1200 cycles to 20 cycles to determine if there was a difference or not. The comparisons were
made for each group separately. Table 8 indicates the results with a significance level of
p. value < 0.01.

<table>
<thead>
<tr>
<th>Group</th>
<th>p. value</th>
<th>Statistical significance at p &lt; 0.01</th>
</tr>
</thead>
<tbody>
<tr>
<td>0P</td>
<td>0.140</td>
<td>Not different</td>
</tr>
<tr>
<td>10P</td>
<td>0.036</td>
<td>Not different</td>
</tr>
<tr>
<td>10G</td>
<td>0.069</td>
<td>Not different</td>
</tr>
<tr>
<td>20G</td>
<td>0.570</td>
<td>Not different</td>
</tr>
</tbody>
</table>

Table 8. Comparison of retention values at 1200 and 20 cycles for each group.

The retention values between 1200 and 20 cycles was not statistically significant
different for any of the groups indicating that the loss of retention of 9% (Table 8) is not
statistically significant.
Variances in retention values

The wide range of sd for the change in retention values deserves some attention. In Figure 31, note that the mean change plotted positive for a loss in retention value. The sd extend so that some specimens probably gained retention over the course of the cycling. This behavior occurred for some of the specimens in all the groups.

Figure 31. Graph illustrating the Mean change in retention values between 20 and 1200 cycles with 1 standard deviation versus the Group (Group 1= 0P, Group 2= 10P, Group 3= 10G and Group 4= 20G).
An analysis of the variances was plotted against a graph for comparison purposes. An interesting observation was that the range of values for the pink nylon (Group 1 and 2) versus the green nylon (Group 3 and 4) at 20 cycles in comparison to 1200 cycles. Comparing the ranges in Figures 32 and 33 indicates that the variances increased at 1200 cycles for the green nylon group (Group 3 and 4). A test of Homogeneity of Variances resulted in a non statistical difference for any of the groups at 20 cycles but, indicated a statistical difference at 1200 cycles. The green inserts exhibited more variance in retention values at 1200 cycles compared to the pink inserts. This may be an indication of a less predictable behavior.

A Test of homogeneity of variances at 20 and 1200 cycles found the variances to be not statistically different at 20 cycles but, different at 1200 cycles.

<table>
<thead>
<tr>
<th>Levene Statistic</th>
<th>df1</th>
<th>df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cycles20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>.971</td>
<td>3</td>
<td>56</td>
<td>.413</td>
</tr>
<tr>
<td>Cycles1200</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.401</td>
<td>3</td>
<td>56</td>
<td>.002</td>
</tr>
</tbody>
</table>

Table 9. Test of homogeneity of variances at 20 and 1200 cycles.
Figure 32. Histogram illustrating the distribution of the specimen for each group
(1= 0P, 2= 10P, 3= 10G and 4= 20G) at 20 cycles.

Figure 33. Histogram illustrating the distribution of the specimen for each group
(1= 0P, 2= 10P, 3= 10G and 4= 20G) at 1200 cycles.
Condition of the abutments

None of the abutments exhibited signs of deformation. The surface, at visual inspection appeared regular in shape in surface texture. There were no signs of abrasion or wear on any areas of the abutments (Fig. 34).

Figure 34. Image of an abutment after 18,000 cycles (magnification 65X).
Figure 35. Image of an abutment after 18,000 cycles showing the collection of debris (circled) and striations (arrows) (magnification 200X).

They all presented a certain amount debris collection distributed overall the surface of the abutment. The amount and distribution of debris collection was not correlated to the angulation or type of insert. The absence of a lubricant like saliva may have contributed to the accumulation of debris. The surface of the abutment presented striations visible at 200X magnification potentially rough and capable of debris retention.
**Condition of the nylon inserts**

All the nylon inserts were compared before and after testing by visual inspection. None of them exhibited deformation detectable by eye. The shape was uniform.

![Pink and green nylon inserts before testing.](image)

**Figure 36.** Pink and green nylon inserts before testing.

After testing, all the inserts were visually inspected. Many of them exhibited debris collection. The debris collection could not be correlated to performance. Some of the debris may have detached and evacuated during testing. The deformation, if it occurred could not be evaluated for correlation. The Locator tool used to remove the inserts may have potentially created deformation and lead to false correlations. The observation under magnification confirmed wear of some of the nylon inserts.
Figure 37. Picture of all the nylon inserts after testing. Note some debris collection indicated by the arrows.

In Figure 37, note the presence of debris indicated by the arrows in many of the inserts. The saturation has been reduced from the picture to facilitate the differentiation between debris (rough appearance) and light reflection (shiny appearance) from the camera flash.
Figure 38. Picture of a magnified view (60X) of 10 degrees green nylon insert after 1200 cycles. Note areas of possible wear indicated by the arrows.

In Figure 38, debris is present at the periphery. Wear is thought to have occurred in the area of the insert indicated by the arrows. In this area, the peripheral width of the insert is thinner.
Figure 39. Picture of a magnified view (60X) of 20 degrees green nylon insert after 1200 cycles. Note areas of possible wear indicated by the arrows.

In Figure 39, debris is present at the periphery. Wear is thought to have occurred in the area of the insert indicated by the arrows. In this area, the peripheral width of the insert is thinner.

None of the 2 caps presented signs of wear due to friction of the inserts.
7. DISCUSSION

The threshold for adequate retention for an overdenture has not been clearly specified. The degree of retention is dependant on the patient’s expectations and satisfaction. Vertical dislodgment forces varying between 7 to 31 N for ball attachments have been reported during In vivo studies. In the present study, a range of 7 to 31 N was considered as a clinically acceptable range of retention for an overdenture.

The overall mean retentions at 20 and 1200 cycles were 49.1 and 45.5 N (Table 7). Clinically, if 7 to 31 N is considered to be an acceptable range of retention for the patient; any statistical analysis is irrelevant since the clinical performance is not affected by these results. Nevertheless, to observe and comment on the behavior of the Locator attachment system, the comparisons planned in the research protocol were executed.

All groups demonstrated a loss in retention values within the first 30 cycles with a stabilizing point at 20 cycles. This behavior was observed by Rutkunas in 2005 with the Locator root pink attachment. He found a drastic decrease, similar to the result in the present study, within the initial 80 cycles. In his study, the behavior was also observed with the Era (white) and Era (orange). The magnet (Magfit EX600W) and OP anchor #4 (ball attachment) did not exhibit this type of decrease. In cycling studies, the establishment of an initial retention value that reflects the clinical scenario is important. At the day of insertion, the overdenture is inserted and removed many times to proceed with adjustments and patient education. This clinical aspect has been taken into account in the present study as well as the behavior observed, and the initial retention value cycle has been established to be at 20 cycles.
Overall, the group 20G exhibited a different behavior compared to other groups according to Figure 26. First, there was a decrease in retention value like the other groups. Second, there was an increase in retention value almost as high as the retention value at cycle 1. And finally, at 1200 cycles, there was a gain in retention value compared to cycle 20. The presence of debris in the inserts could not be correlated to the behavior (Fig. 37), but it appeared that the debris remained inside of the insert more than with the other groups. The angulation of the implants may have played a role on how the debris was either evacuated or pushed inside when it was detached from the inserts. The presence of debris inside of the nylon could have increase the retention for the period the debris remained inside. Another factor that may have played a role is the lot this product came from. The quality of the nylon may have been affected by storage or a problem with fabrication despite they appeared similar in size and texture to the other inserts before the cycling. Another factor to take into account is the effect of cycling on nylon. The angulation may have created more friction than the other groups and the nylon may have become stiffer as a reaction. An increased stiffness could be responsible for an increased retention. Despite these findings, the 20G group was kept for comparisons since there was no way to identify the cause for this behavior, which may well have been related to angulation. The fact that the general behavior was within the results of the other groups also favored keeping it for comparisons.

The impact of implant angulation on initial retention values was surprising. The pink inserts groups did not have a significant statistical difference whether the angulation was 0° or 10°, but the green group had a statistically significant difference between 10° and 20°. The 10° had more initial retention then the 20°. Based on the 10P or 0P and 10G
and 20G (Table 5), it can be concluded that angulation decreases retention value for the green insert but not for the pink insert.

The impact of the type of nylons on initial retention values can be based on the following observation: the 10G presented a higher retention value at 20 cycles when compared to the 10P. This indicates that the pink insert at 10° will exert less retentive force than the green insert. This is surprising since the pink insert is designed with a Dual Retention feature to increase its performance in contrast to the green insert that does not have this feature. The difference was substantial and may be clinically relevant. If 7 to 31 N is considered to be a clinically acceptable range of retention, the clinician may consider using the pink insert instead of the green at 10 degrees. The retention was respectively for 10P and 10G, 37.1 N and 71.3 N (Table 4). A retention value of 71.3 N may be too high for the patient to easily remove an overdenture from his/her mouth.

The change in retention values between 1200 and 20 cycles was -4.4N±12.3 (Table 7). A value that was not statistically significant since when comparing 1200 to 20 cycle, the difference was not statistically different for each of the group (Table 8). The variances in values are responsible for this result along with the small sample size (n=15). When exploring the variances in retention change for each group independently, it was observed that all the groups gained and loss retention value over 1200 cycles to different levels. In group 0P, 10P and 10G, 5/15 (30%) of the specimen gained retention. In group 20G, 9/15 (60%) of the specimen gained retention as described in table 10.
### Table 10.

Wilcoxon signed ranks test illustrating the number of specimen that gained or lost retention value after 1200 cycles.
The gain in retention could be explained by the debris retention as described earlier for group 20G or by the effect of cycling on nylon. The heat generated by friction may increase the stiffness of the material and indirectly, the retention. In an intra-oral environment, this effect could be different. Oral fluids may act as a lubricant and temperature buffer reducing the consequences of friction of the abutment against the nylon. In vivo, a few hours would elapse between the insertion and removal of the overdenture by the patient during the day. This is an important factor to consider since in this study, only 2 seconds were allowed for the nylon inserts to recover between insertion and removal and vice versa.

The impact of implant angulation and the type of nylon on the change of retention was not statistically significant different for all the groups (Table 6). However, the variances in sd for the change in retention values deserve some attention (Fig. 32 and 33). The green inserts exhibited more variances in retention values at 1200 cycles when compared to the pink inserts. The variances at 20 cycles were not statistically significant different between all groups (Table 9). This may be an indication of a less predictable behavior of the green inserts with time in use. As they were submitted to cycling, the green insert groups tended to have a wider range of variances. 6 specimens lost substantial retention value and 9 (60%) gained retention (Table 10). Again, these results should be evaluated in the context of the overall performance of the system, which indicated initial and final retention that were higher in than the range of clinically acceptable retention values for an overdenture.
The impact of 1200 cycles on the condition of the abutments and nylons were as expected. The abutments did not exhibit any signs of wear after 18,000 cycles. They did not become loose throughout the experimental cycling.

The inserts all exhibited signs of minor wear or debris accumulation that could not be correlated since there was no statistical difference in change of retention between groups.

The following Null Hypotheses were:

1) Implant angulation does not affect retention value change: accepted.
2) Implant angulation does not affect initial retention values: accepted for the pink nylon at 0° and 10° but rejected for 10° and 20°.
3) 1200 cycles does not affect initial retention values: accepted
8. CONCLUSIONS

The mean overall initial and final retention values for the Locator attachment system were 49.9 N and 45.0 N. A clinically acceptable range of retention for an overdenture of 7 to 31 N was determined as a reference in this study. Overall, the Locator attachment system lost a mean retention value of 4.4±12.3 (9%) after 1200 cycles, a result that was found to be not statistically significant. Therefore, the Locator attachment system (pink and green insert) did not lose a clinically and statistically significant retention value after 1200 cycles. Within the limitations of this study, the pink inserts exerted a statistically significant lower initial retention value (38.6 N) than the green inserts (61.5 N) at 10 degrees. This is an important factor to consider in the selection of the nylon insert to achieve an appropriate level of retention of the overdenture. The patient may have difficulties removing an overdenture that is too retentive. The angulation of the implant had no impact on the initial retention value of the pink nylon inserts between 0 and 10 degrees but presented a statistically significant higher value at 10 compared to 20 degrees for the green nylon inserts. Finally, the variances in values at 20 and 1200 cycles for all the specimens indicated that the green insert had statistically more variances at 1200 cycles. This finding combined with the behavior the 20G group may be an indication of a less predictable behavior of the green inserts. A behavior that is not clinically significant since the final retention was higher than the clinically acceptable range of retention used in this study. The Locator attachment system (green and pink) presented an excellent performance after 1200 cycles in vitro.
9. FUTURE WORK

In this study, 4 factors may have made a difference in the results: 1) the number of specimens; 2) the amount of cycling; 3) the presence of a fluid simulating intra-oral environment and; 4) the length of time that the pause lasted between insertion and removal of the attachment system. It would be interesting to repeat the same experiment for a period of cycling twice longer, with a number of specimens equal to 30 in each group instead of 15, in the presence of a fluid simulating the oral environment and, with a longer period of time between insertion and removal of the overdenture. This may explain the behavior of the inserts that have gained retention possibly due to increased stiffness of the nylon. A drastic loss of retention may be observed after the nylon material transformation has reached a point that has a sudden negative impact on the elastic and recovery properties of the nylon insert.
10. REFERENCES


