Eur. J. Prosthodont. Rest. Dent., Vol.20, No. 4, pp 168-174
Printed in Great Britain

doi:10.1922/EJPRD_ 1136Radford07

The Retentive Forces of the Locator Attachment System at Different Angulations

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Abstract - *The change of retentive force of three types of Locator inserts when the implant analogue was positioned perpendicular to horizontal, 5º and 10º to perpendicular after 4,200 cycles in vitro was measured using an Endura-Tech fatigue testing machine lubricated with artificial saliva. The more rapid decrease in retention occurred up to three months and stabilized after one year of simulated use. The Locator inserts provided more retention when the analogue was placed at 5º to perpendicular compared to 0º and 10º after 9 months of simulated clinical use. After 2 years of simulated clinical use, there was a reduction in retention for all the three inserts of between 70% and 80%.*

KEYWORDS: Implant attachment, Implant angulation, Attachment wear, Attachment retention.

INTRODUCTION

Implant retained overdentures have been shown to be a highly successful prosthetic treatment for the edentulous patient. In comparison to a conventional denture, implant retained overdentures provide not only enhanced retention and stability but also improved patient satisfaction and quality of life[1-4]. The McGill consensus statement 2002[3] and the York consensus statement 2009[4] recommend that the placement of two implants in the mandible should be the first choice standard of care option for edentulous patients.

Retention of implant-retained overdentures is achieved by means of mechanical devices, such as stud attachments, bars and magnets[5]. However, despite the ongoing research for the "ideal" attachment by the manufacturing companies, most of the attachments seem to be susceptible to wear or damage over time especially during the first year of clinical use. Wear is the process by which material is displaced or removed by the interfacial forces that are generated as two surfaces rub together[6]. This material loss at the attachment surface occurs either during insertion and removal of the prosthesis or under movement of the denture during functional or parafunctional activities due to friction between the male and female parts of the attachment.

A considerable number of *in vitro* fatigue tests have been undertaken to measure the change in retentive forces of different types of attachments due to wear. Different types of attachments have demonstrated different wear behaviour and no correlation can easily be made between the type or material of the attachment and certain wear behaviour. Setz *et al*[7] demonstrated attachments showed little wear after 15,000 cycles, whereas Rutkunas *et al*[8] showed stable retention after 800 cycles. In other studies some of the examined attachments demonstrated initial increase in retentive force[9-11], whereas in the study by Botega *et al*[10], all the examined attachments demonstrated increasing retention even after 5,500 cycles. *In vitro* studies do not provide a clear picture and the retentive forces of different types of attachment vary significantly[12-16]. The evaluation of retentive properties of different types of attachments has significant clinical implications for the clinician, as they should be able to select the appropriate type of attachment for the specific clinical situation.

These results contrast with *in vivo* studies that confirmed wear of the attachments over time[17-21]. This may be explained by the fact that *in vitro* studies, the wear pattern was simplified and well controlled as the forces were applied exclusively along the path of insertion. In the oral environment, the overdenture is subjected to various minimal movements during function (i.e. mastication), or even parafunction that can affect the retentive properties of the attachments.

The frequent episodes of maintenance that occur clinically using most types of attachments especially the first year after function, contrast with many of the *in vitro* results of the previous studies[7-11]. This probably indicates that with regard to the wear behaviour of the attachments, functional or parafunctional loading are more crucial factors than the repeated insertion and removal of the attachments.

The Locator attachment is an extraradicular universal hinge attachment, which consists of a titanium abutment with titanium nitride cap, and a nylon insert and was designed for use of overdentures or partial dentures retained by endosseous implants in the mandible or maxilla. The standard range includes three different types of nylon inserts (clear, pink and blue) that provide different degrees of retention and are used for parallel or slightly angulated implants. The retentive properties of the clear nylon insert are stated by the manufacturer to require a force of 22.24N to separate the two components, the pink insert requires 13.34N force and the blue 6.67N.

Most studies have used 2 implant analogues placed 22mm apart representing the inter-canine distance and therefore, simulating the clinical situation[7,10]. No study reports meas-

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urement of the change in retentive force of an individual attachment after a number of cycles when placed parallel to the direction of withdrawal or at different angles to perpendicular.

The aim of the study was to measure the possible change in retentive force of each of the 3 different types of nylon Locator inserts during and after 4,200 cycles, when the implant analogue was placed at 0º, 5º and 10º angulations to the perpendicular path of withdrawal.

MATERIALS AND METHODS

Three 3.5-4.0mm diameter implant replicas were cemented with epoxy resin adhesive in aluminium blocks (35mm in length, 15mm in height and 10mm in width) at 0º 5º and 10º angulations to the horizontal level respectively. 3.5-4.0mm diameter Locator abutments were attached to the implant analogues and were tightened using the Locator torque wrench so as to achieve the minimum seating force of 20N-cm (Fig. 1).

A Locator metal housing was cemented to corresponding aluminium blocks using Metal Primer II and a light curing denture resin. During the cyclic loading test, 15 Locator inserts, 5 of each colour (clear, pink and blue) were inserted in each metal housing using the Locator core tool.

The Bose EnduraTech 3300 testing machine, which was used is a precision instrument that allows rapid and accurate engagement and disengagement along a controlled path of specimens such as those being tested. The machine was set to a frequency of 2 cycles/second (2Hz) at a speed of travel of 8mm/second. For each test, the machine was calibrated to zero displacement and zero load at the start position, which was full engagement of the Locator attachment. The displacement was adjusted to range between ±2mm to ensure full engagement and disengagement of the Locator attachment during the cyclic test.

The entire assembly was lubricated with artificial saliva at 23ºC by a peristaltic pump[7]. The EnduraTech Testing machine was adjusted to carry out 4,200 cycles with a frequency of 2 cycles/second (2Hz) at a speed 8mm/sec. A cycle is defined as one complete process of engaging and disengaging the matrix and patrix[9]. In the present study, the engagement and disengagement of the Locator attachment system was carried out at right angles to the horizontal level. Four thousand cycles are equivalent to approximately 2.3 years (2.3 x 365 x 5 = 3832) of simulated clinical use, under the assumption that the patient removes his denture 5 times daily[22]. After the completion of each test data was downloaded. Eighteen data points which represented baseline, 3, 6, 9, 12, 18, 24 and 27 months, were extracted from the plots produced. A total of 15 Locator inserts, 5 of each colour (clear, pink and blue) were tested.

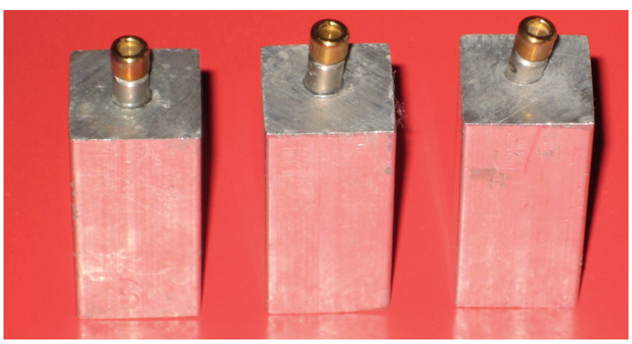

Figure 1. *Aluminium blocks with the Locator abutments orientated at 0°, 5° and 10°*

The results exhibited a Normal distribution; therefore, mean and standard deviation were calculated. A two-way Analysis of Variance (ANOVA) was used to determine whether there were significant differences in retention between different types of inserts and different angulations. In cases where differences were found, further post-ANOVA analysis was performed, using the Scheffé test. Levels of probability lower than 0.05 ($p<0.05$) were considered to be statistically significant.

RESULTS

Tables 1-8 give the mean force required for separation and standard deviation in Newtons of each type of insert when placed perpendicular to the horizontal plane, at 5º and 10º to the perpendicular. In addition, the mean force required for separation of each type of insert at any of the three angulations was calculated and referred to as Total I. The mean force for disengagement of each angle for all the three inserts was referred to as Total II.

The results indicated that regarding the mean force at baseline (Table 1) and after 3 months of simulated use (Table 2), there was no statistically significant difference between the different types of inserts at any of the 3 angles and no statistically significant difference among the different angles in any of the three different inserts used. After 6m, 9m, 12m, 18m, 24m and at the end of the test, the mean force required for separation was significantly different between the clear and the blue inserts in general (Tables 3-8) with the clear insert being significantly higher than the blue insert. Regarding the different angles, there was statistically significant difference in force at separation after 9m, 12m, 18m, 24m and the end of the test, between the 5º and 10º with the mean force at 5º, being statistically higher compared to that of 10º (Tables 4-8). The force at separation at the intervals of 9m, 12m, 18m, 24m and minimum was higher, but not statistically different when the implant was angulated at 5º to the perpendicular comparing to the perpendicular one (Tables 3-8). The minimum force ranged from 5.2N-12.0N with standard deviation 1.2N-4.1N for all the types of inserts at all the three angles.

Figures 2,3,4 illustrate the mean and standard deviation of the force at disengagement of the three types of inserts at 0º, 5º and 10º angle to the perpendicular. The decrease of the force at disengagement, at a different rate over time, was noticed in all the three types of inserts, at all 3 angles. The rate of decrease of the retentive force was higher during the first 6 months and especially the first 3 months of simulated clinical use. However, it appeared to stabilize after one year of clinical use for all the types of inserts at all angles. The clear insert demonstrated higher retentive force at baseline at 0º and 5º, whereas the blue insert at 10º. At 0º, the mean force at disengagement at baseline coincided for the blue and pink insert (Figure 2). The standard deviation was high at the baseline, at 3 and 6 months of simulated clinical use in all three inserts; however, it reduced and became more stable after 9 months of simulated clinical use.

Table 1. *Mean and standard deviation of the force at separation in Newtons at baseline*

	Angle				
Colour	0°	5°	10°	*Total I*	*P value*
Blue	33.8 (6.4)	25.1 (9.2)	34.7 (10.6)	31.2 (9.4)	0.272
Pink	33.2 (4.3)	28.1 (11.1)	25.5 (7.2)	28.9 (8.1)	
Clear	38.5 (4.6)	34.2 (1.9)	30.5 (17.3)	34.4 (10.2)	
Total II	35.2 (5.4)	29.2 (8.7)	30.2 (12.2)		
P value		0.171			

Table 2. *Mean and standard deviation of the force at separation in Newtons after 3 months*

	Angle				
Colour	0°	5°	10°	*Total I*	*P value*
Blue	18.5 (4.1)	16.3 (4.2)	16.2 (7.1)	17.0 (5.1)	0.075
Pink	27.8 (8.6)	22.3 (6.8)	18.5 (4.9)	22.9 (7.5)	
Clear	22.6 (13.2)	22.3 (1.9)	17.6 (5.1)	20.8 (8.0)	
Total II	23.0 (9.5)	20.3 (5.3)	17.5 (5.4)		
P value		0.108			

Table 3. *Mean and standard deviation of the force at separation in Newton after 6 months*

	Angle				
Colour	0°	5°	10°	*Total I*	*P value*
Blue	12.2 (2.2)	13.1 (3.6)	11.0 (3.0)	12.1 (2.9)*	0.015
Pink	19.4 (6.3)	17.1 (4.4)	13.8 (5.1)	14.8 (5.5)	
Clear	15.4 (7.0)	18.6 (1.0)	12.9 (3.1)	15.6 (4.8)*	
Total II	15.7 (6.0)	16.3 (3.9)	12.6 (3.8)		
P value		0.056			

** levels of each category that are different (post-ANOVA contrasts, p<0.05)*

Table 4. *Mean and standard deviation of the force at separation in Newtons after 9 months*

	Angle				
Colour	0°	5°	10°	*Total I*	*P value*
Blue	10.0 (2.1)	10.7 (2.5)	8.6 (2.5)	9.8 (2.4)*	0.002
Pink	15.8 (4.4)	14.5 (3.4)	11.7 (4.2)	13.8 (4.1)	
Clear	13.4 (5.6)	16.6 (0.7)	11.8 (3.4)	13.9 (4.1)*	
Total II	13.1 (4.7)	13.9 (3.4)**	10.7 (3.5)**		
P value		0.041			

** levels of each category that are different (post-ANOVA contrasts, p<0.05)*
*** levels of each category that are different (post-ANOVA contrasts, p<0.05)*

Table 5. *Mean and standard deviation of the force at separation in Newton after 12 months*

	Angle				
Colour	0°	5°	10°	*Total I*	*P value*
Blue	8.7 (1.9)	10.8 (2.8)	7.9 (2.8)	9.2 (2.7)*	0.004
Pink	12.5 (2.3)	13.3 (2.9)	10.8 (4.3)	12.2 (3.2)	
Clear	12.7 (5.1)	15.4 (0.5)	10.8 (3.2)	13.0 (3.8)*	
Total II	11.3 (3.7)	13.2 (2.9)**	9.9 (3.5)**		
P value		0.021			

** levels of each category that are different (post-ANOVA contrasts, p<0.05)*
*** levels of each category that are different (post-ANOVA contrasts, p<0.05)*

Table 6. *Mean and standard deviation of the force at separation in Newtons after 18 months*

		Angle			
Colour	0°	5°	10°	*Total I*	*P value*
Blue	7.1 (2.0)	9.3 (2.4)	7.3 (2.8)	7.9 (2.5)*	0.003
Pink	10.8 (1.6)	11.3 (1.8)	9.0 (3.9)	10.4 (2.7)	
Clear	11.5 (4.7)	13.8 (0.7)	9.6 (3.4)	11.6 (3.6)*	
Total II	9.8 (3.5)	11.5 (2.5)**	8.6 (3.3)**		
P value		0.031			

** levels of each category that are different (post-ANOVA contrasts, p<0.05)*
*** levels of each category that are different (post-ANOVA contrasts, p<0.05)*

Table 7. *Mean and standard deviation of the force at separation in Newtons after 24 months*

		Angle			
Colour	0°	5°	10°	*Total I*	*P value*
Blue	6.2 (1.4)	8.4 (2.5)	6.1 (2.5)	6.9 (2.3)*	0.001
Pink	10.0 (2.0)	10.0 (1.9)	8.3 (3.8)	9.4 (2.6)	
Clear	10.2 (4.4)	12.9 (0.6)	9.0 (3.2)	10.7 (3.4)*	
Total II	8.8 (3.3)	10.5 (2.6)**	7.8 (3.2)**		
P value		0.035			

** levels of each category that are different (post-ANOVA contrasts, p<0.05)*
*** levels of each category that are different (post-ANOVA contrasts, p<0.05)*

Table 8. *Mean and standard deviation of the force at separation in Newtons at the end of the cycling test*

		Angle			
Colour	0°	5°	10°	*Total I*	*P value*
Blue	5.5 (1.7)	7.2 (1.7)	5.2 (1.8)	6.0 (1.8)*	<0.001
Pink	9.5 (2.4)	9.1 (1.9)	7.0 (3.8)	8.5 (2.8)	
Clear	10.0 (4.1)	12.0 (1.2)	8.3 (2.9)	10.1 (3.2)*	
Total II	8.3 (3.4)	9.4 (2.5)**	6.8 (3.0)**		
P value		0.030			

** levels of each category that are different (post-ANOVA contrasts, p<0.05)*
*** levels of each category that are different (post-ANOVA contrasts, p<0.05)*

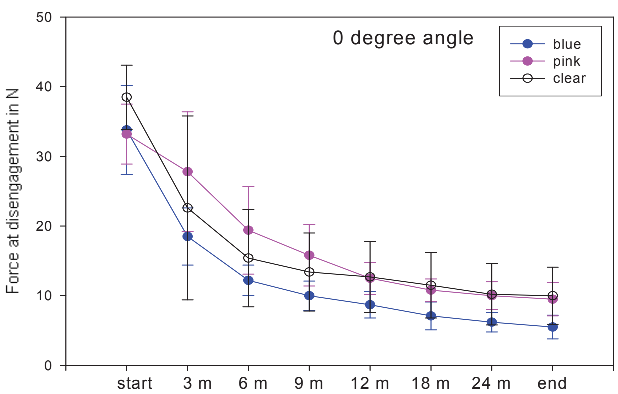

Figure 2. *Mean and standard deviation of the force at disengagement for 0° angle*

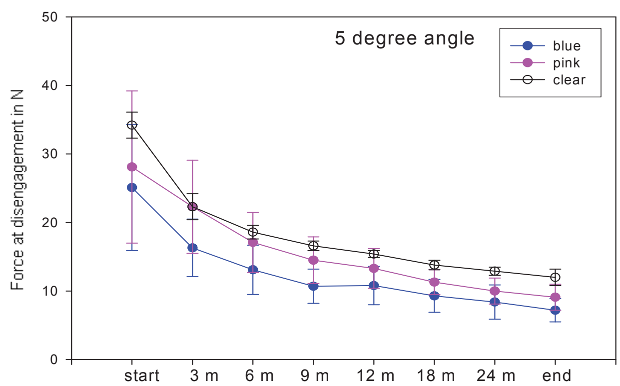

Figure 3. *Mean and standard deviation of the force at disengagement for 5° angle*

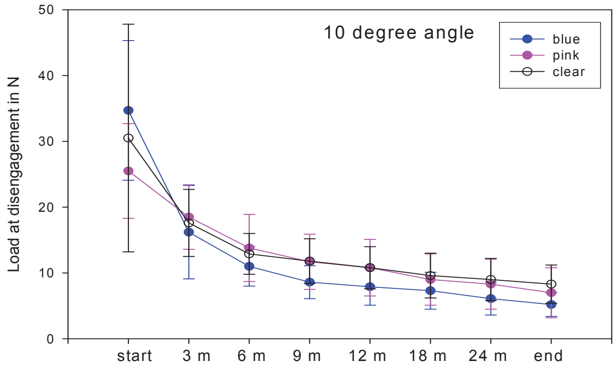

Figure 4. *Mean and standard deviation of the force at disengagement for 10° angle*

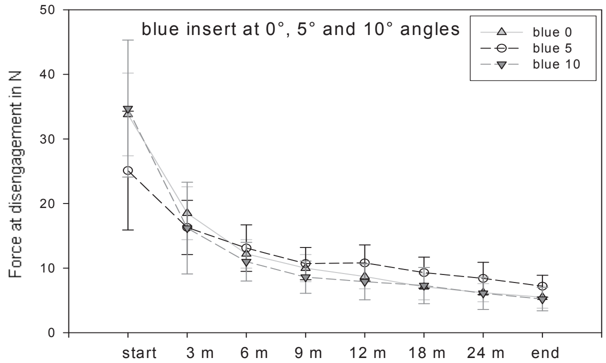

Figure 5. *Mean and standard deviation of the retentive force for the blue insert*

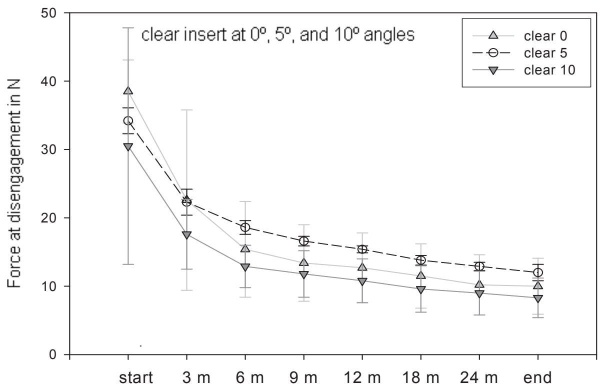

Figure 6. *Mean and standard deviation of the retentive force for the clear insert*

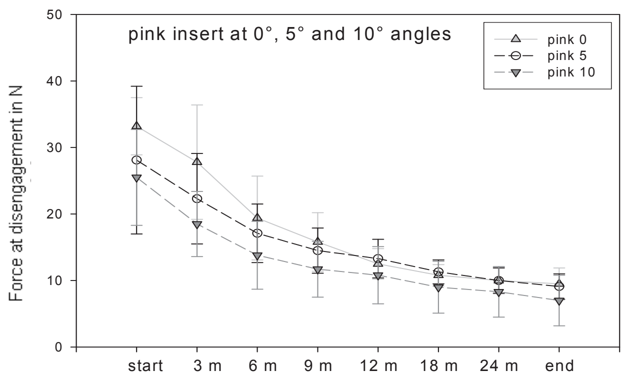

Figure 7. *Mean and standard deviation of the retentive force for the pink insert*

Figures 5,6,7 illustrate the mean value and standard deviation of the force at disengagement of each type of insert at 0º, 5º and 10º to the perpendicular. A rapid drop of the force at disengagement was noticed during the first 3 months of simulated use, especially for the blue and clear inserts at all the 3 angles (Figures 3,4).

DISCUSSION

The maximum force required to disengage the attachments at any of the three different angles ranged between 25N-38.5N, which is within the wide range (3N-85N) of initial retentive force of different types of attachments for implant retained overdentures[7]. The maximum retentive force for each type of Locator attachment in the present study was much higher than the manufacturer's quote when implants are placed parallel to the path of withdrawal. In the study by Chung *et al*[14] the mean retentive force for the clear insert was 35.24N, which is close to the figure of the present study whereas for the pink insert the mean load to dislodgement was 12.33N, very close to the manufacturer's figures. The present study cannot be directly compared with the study by Chung *et al*[14] as the latter evaluated the retentive force of a pair of Locator attachments placed parallel whereas the present study investigated single Locator attachments.

Force at disengagement decreased at different rates over time for each colour of retaining inserts, which confirms that Locator attachments do wear significantly over time. In addition, the results of the present study contrast with some of the *in vitro* studies that refer to an increase of retentive force of some attachments during the cycling test. According to Stewart and Edwards[9], one attachment for root retained overdentures demonstrated an increase in retentive force after 2,200 cycles. Setz *et al*[7], observed an initial increase in retentive force of 4 of the attachments for implant retained overdenture after 1,500 cycles, whereas Wichmann and Kuntze[11], confirmed a reproducible increase of retention of one plastic attachment during the first 1,000 cycles and Gamborena *et al*[20], observed an increase in retentive force of some of the ERA attachments between 3,000 and 3,500 cycles.

The results of the present study showed that there was no statistically significant difference in the mean retentive force after 3 months of simulated clinical use for all the three types of attachments at all the three angles. The clear insert demonstrated higher force of disengagement at baseline at 0º and 5º to the perpendicular, which confirmed the manufacturer's assertion that the clear insert is the most retentive, if their figures refer to the retentive force at baseline.

After 6 months and throughout the cycling test, there was a statistically significant difference in the force at disengagement between the clear and the blue insert generally, with the clear insert having a statistically higher force of disengagement than the blue one. This may mean clinically that the clear insert may be the best option for the patient in terms of cost effectiveness. The present study showed that although the manufacturer indicated three different retentive elements, only two become significantly different after 6 months of clinical use. This conclusion is in agreement with that of Gamborena and colleagues[20], who evaluated the retentive properties and wear behaviour of the ERA attachments.

Comparing the different angulations, there was no difference between the three angles that the analogue was placed for any of the types of Locator inserts for the first 6 months of simulated clinical use. This would mean clinically that the three types of Locator inserts can be used when the implant is slightly angulated for a reasonable period of time. This conclusion is in agreement with the manufacturer's indications that resilient Locator attachments can compensate for slight angulation of the implants without loosing their retentive characteristics. This observation is clinically important as it is difficult in clinical practice to place the implant exactly at 0º to the perpendicular[23] or exactly parallel to other implants or the path of withdrawal of the denture. However, the present study tested an individual Locator attachment. In clinical practice a single implant is rarely used. Further studies would need to evaluate the retentive properties of two or more Locator attachments set at different angles to each other.

However, after 9 months of simulated wear, there was a statistically significant difference in the force of disengagement between the 5º and 10º angulations of the implant analogue, with the force of disengagement at 5º being statistically higher than the 10º. Therefore, the second null hypothesis was rejected. The force at disengagement for 0º to all the types of inserts was lower than 5º, higher than 10º but not statistically different from either of them. These results cannot be easily explained. However, the most retentive combination according to the present study seemed to be the clear insert at 5º and the least retentive seemed to be the blue insert at 10º throughout the fatigue test. This may mean clinically that the clear insert should be preferred when the implant is placed at 5º angulation, whereas the blue insert should be avoided when the implant is placed at 10º. However, further studies need to confirm these conclusions.

At the end of the cycling test and after approximately 2.3 years of simulated clinical use, the force at disengagement of the blue insert dropped from 31.2N to 6.0N (80.7%), the pink from 28.9N to 8.5N (70.5%) and the clear from 34.4N to 10.1N (70.6%).

CONCLUSIONS

Within the limitations of the current study the following conclusions can be drawn:

During the test, which represented approximately 2.3 years of simulated clinical use, there was a decrease in the force at disengagement for all the types of Locator inserts, at different rates over time. The more rapid decrease in the retentive force for all the Locator inserts occurred up to 3 months of simulated clinical use and stabilized after 1 year.

There was no significant difference in the retentive force among the three types of Locator inserts following 3 months of simulated clinical use.

Following 2 years of simulated clinical use, the loss of retention for all the three types of inserts was significant and ranged between 70.5% and 80.7%.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the advice of Professor R.M. Palmer in study design and Dr R. Wilson for help with statistical analysis.

MANUFACTURER'S DETAILS

- Zest Anchors Inc., Escondido, California
- Astra Tech Inc., Molndal, Sweden
- RS Components, Corby, England
- GC Corporation, Tokyo, Japan
- Acrifix, Friedberd, Germany
- Bose Corporation, Minnesota, USA

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