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Evaluation of stable retentive properties of overdenture attachments

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SUMMARY

Objectives: To evaluate fatigue of stud (ERA Overdenture (orange and white), Locator Root (pink) and OP anchor # 4) and magnetic (Magfit EX600W) attachments by measuring maximum retentive force. To compare retentive force of overdenture attachments after their reach stable retention. To determine minimum number of cycles required to reach stable retention.

Material and methods: Three specimens of each type of attachment were used. Micromaterial testing machine (MMT-250NB-10, Shimadzu Co., Tokyo, Japan) with a sensor interface PCD-320 and software package PCD-30A (Kyowa Electronic Instruments Co., Tokyo, Japan) was used to performe 2000 insertion-removal cycles with 50 mm/min cross head speed. Maximum retentive force was measured initially and after each 40 cycles. Statistical analysis: paired-samples t-test, one-way ANOVA and Scheffe post-hoc tests ($P<0.05$).

Results: Before and after fatigue simulation statistically significant differences existed among the five types of attachments. Decrease of retention was characteristic for all attachments except OP. After fatigue LRP was most retentive. Magnetic attachments preserved maximum amount of retention measured at the baseline (98%). EO and EW attachments have preserved only 25% and 37% of initial retention respectively.

Conclusions: Due to fatigue overdenture attachments gradually loose their retention. Stud attachments are more susceptible to fatigue than magnets. Eight hundred cycles are required to achieve relatively stable retention of overdenture attachments.

Key words: overdenture, studs, magnets, retention, fatigue.

INTRODUCTION

Annual alveolar ridge height reduction was showed to be approximately 0.4 mm in the edentulous anterior mandible, while long-term bone resorption under an implant overdenture may remain at 0.1mm annually [1,2]. Only slight increase in retention, stability, and occlusal equilibration of overdenture was achieved with more than two implants [3]. Therefore, due to simplicity, comparatively low costs [4], and similar efficiency as with fixed implant supported mandibular prostheses [5], two-implant supported mandibular overdentures have been considered by some as the standard of care for edentulous patients [6]. Similarly mandibular overdentures retained by remaining natural roots allowed to avoid problems associated with complete dentures. Patient satisfaction with overdentures is influenced by various factors including denture quality, the available denture bearing area, the quality of dentist-patient interaction, previous experience with dentures, patient's personality and psychologic well-being [7]. Many studies have addressed the influence of the overdenture retainer type on burden of maintenance [8], maximum occlusal force [9], masticatory function [10], patient satisfaction [11,12], and retention and stability [13].

The influence of load transfer from the prosthetic super-structures to the supporting implants is still under investigated and reports of studies are inconclusive [14,15]. The highest strains in implant-bone interface occurred with rigid telescopes, and ball and magnet attachments having better load transfer pattern than bars [16]. However, no difference in implant survival rate, health of peri-implant tissue, or marginal bone loss between different attachment systems retaining mandibular overdenture was found [17,18].

Retention is a key element in the removable prosthodontics. There is strong evidence that retention is of great importance for a patient's satisfaction. By using a cross-over experimental design, Burns et al. found a strong patient preference for the overdenture attachment with superior retention [19]. The lower retention of the mandibular overdenture and the lower resistance against horizontal movements may lead to less denture stability during chewing and thus to a reduced masticatory performance [20]. Thought many factors such as proper border extensions, adhesion, neuromuscular control etc. contribute to the retention of mandibular overdenture, still overdenture attachments play a chief role. Bars, studs and magnets are widely used. Simple, cheap and effec-

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Table 1. Overdenture attachments tested

Type	Abbreviation	Manufacturer
OP anchor #4	OP	Inoue Attachments. Tokyo. Japan
Locator Root (pink)	LRP	Zest Anchors. Escondido. USA
ERA Overdenture (white)	EW	Sterngold. Attleboro. USA
ERA Overdenture (orange)	EO	
Magfit EX600W	MF	Aichi Steel. Aichi. Japan

tive application of studs and magnets are appreciated by the clinicians and patients. Controversy exists which type of attachments require less servicing in post-insertion period. Other factors not related to the type of overdenture attachment were also addressed as playing important role [21].

Among all implant restorations loosening of overdenture retentive mechanisms were identified as the most common (33%) prosthodontic complication [22], therefore, routine maintenance is required to ensure successful long-term outcomes [23]. Fatigue or failure of overdenture attachments adversely affects function, maintenance aspects, and patient satisfaction [24]. The burden of matrix maintenance is paramount for the prosthodontist, regardless of type of attachment used. Exchange of rubber O rings was recommended either annually or biannually depending on the number of implants used [25]. It was found that clip adjustments occurred in 62% of cases during a 5-year evaluation period, 32% of which during first 12 months [26]. Some authors reported that 55% of the clinician's time would be involved in replacing retentive components [27].

Initially attachments have unstable retentive properties [28]. After an appropriate number of insertion-removal cycles, attachments obtain more stable properties, which better represent the post-insertion period [29]. Accordingly, it is appropriate to evaluate retention of attachments in this post-insertion period, and not limit it to assessment only initially [30]. Retentive device will serve little clinical purpose if due to fatigue it will loose its retention after few weeks. Therefore, fatigue behavior is a critical characteristic of overdenture attachments [31]. Due to the nature of magnetic forces magnetic attachments do not loose the retentive force unless they are damaged by corrosion [32]. New generation of magnetic attachments claim reliable corrosion protection [33].

Considering aspects mentioned above the following aims were selected: 1) to evaluate decrease of retentive force of different overdenture attachments during consecutive insertion-removal cycling; 2) to determine minimum number of cycles required to achieve relatively constant retentive properties for tested attachments; 3) to compare fatigue behavior of stud and magnetic overdenture attachments.

MATERIALS AND METHODS

Four commercially available stud and one commer-

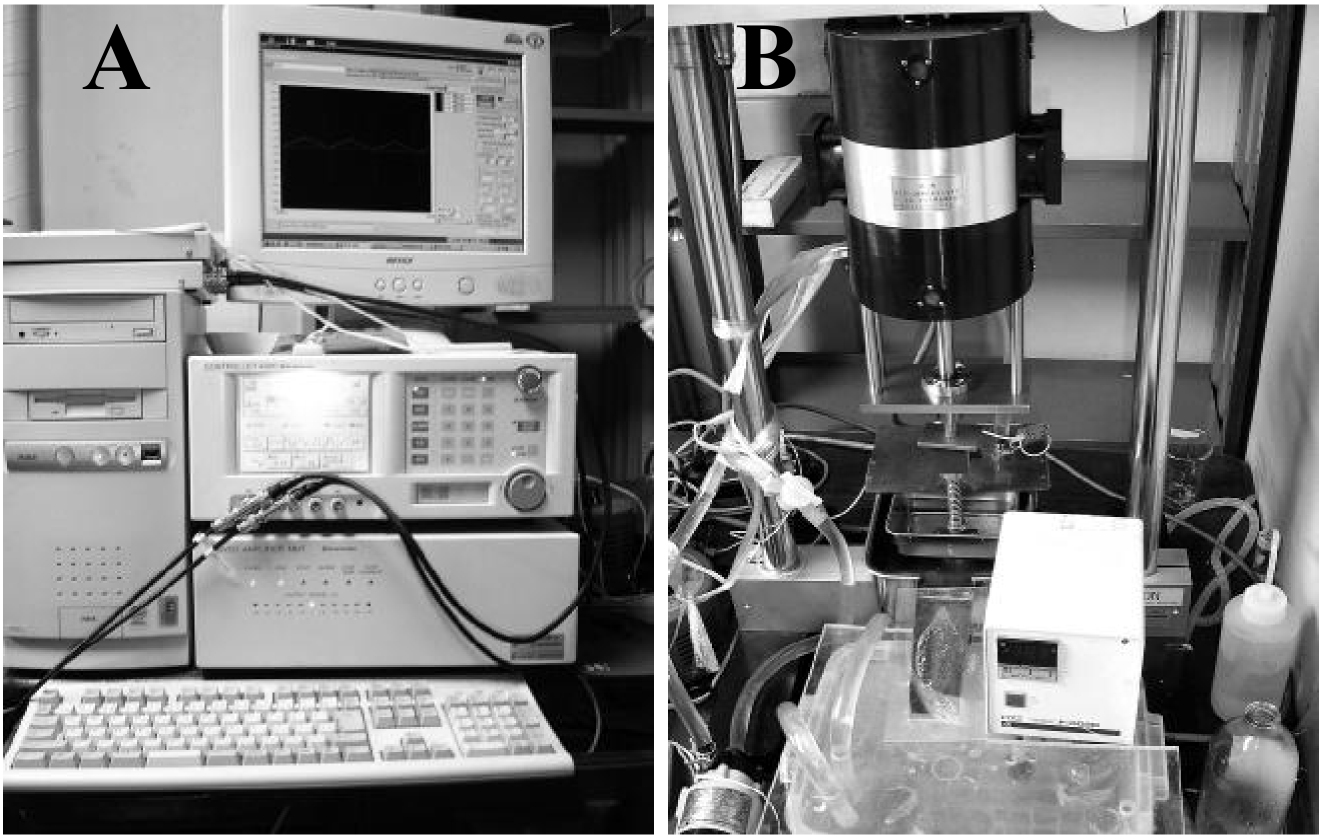

Fig. 1. For testing and simulating overdenture attachment fatigue micromaterial testing machine (MMT-250NB-10, Shimadzu Co.) (A) and sensor interface PCD-320 with software package PCD-30A (Kyowa Electronic Instruments Co.) (B) were utilized

Table 2. Comparison of retentive force of overdenture attachments before and after fatigue simulation (P>0.05)

Type	Before fatigue Mean	Before fatigue SD	After fatigue Mean	After fatigue SD	Absolute change	Change %	Sig. (2-tailed)
OP	3.26	0.40	4.46	0.30	-1.20	136.62	0.020
LRP	8.88	2.99	6.14	0.43	2.73	69.21	0.000
EW*	9.59	4.69	3.53	0.82	6.06	36.81	0.002
EO*	12.27	3.82	3.06	0.22	9.21	24.94	0.000
MF	5.57	0.05	5.46	0.03	0.11	98.10	0.000

* - not statistically significant difference after fatigue simulation. Results of Scheffe post-hoc test (P<0.05).

cially available magnetic overdenture attachments (n=3 specimens for each attachment type) comprised test group (Table 1). Specimens of attachments were prepared in way described previously [31]. Micromaterial testing machine (MMT-250NB-10, Shimadzu Co., Tokyo, Japan) with a sensor interface PCD-320 and software package PCD-30A (Kyowa Electronic Instruments Co., Tokyo, Japan) were used to test and simulate fatigue (Fig. 1 a,b). The tooth (implant) component of the attachment was attached to a jig (Fig. 2) and the jig was connected to a load cell of fatigue machine by means of magnetic holder. The jig was specially constructed in order to achieve highly reproducible movement of insertion-removal, otherwise parts of attachments could be broken. The metal ring containing the denture component of the attachment was seated on its counterpart and secured to the screw fixed at the bottom of the bath by auto-polymerizing resin (Unifast Trad, GC, Tokyo, Japan). After polymerization of the resin, the bath was filled with demineralized water. It was warmed up to 37° C by 38° C water circulating outside the bath (Fig 3). Then 2000 consecutive cycles of removal and insertion were performed under the following conditions: 2.5 mm dislodgement, 50 mm/min dislodgement speed and 100 Hz sampling rate. This model permitted to perform and evaluate dislodgement in axial direction only. Initially, and after each 40 cycles, 3 records of maximum retentive force (N) were recorded and averaged for each specimen. Absolute and percentage changes in retention force were calculated and analyzed. Also retention of stud and magnetic attachments as well as fatigue behavior was compared.

In order to determine minimum number of cycles required to achieve relatively constant retentive properties all measurements were divided into 5 groups according to the number of cycles: 0-400, 400-800, 800-1200, 1200-1600, and 1600-2000. Mean values between each 2 successive groups were compared for each specimen using paired-samples t test (SPSS ver.11 for Windows, SPSS Inc., Chicago, Ill). The lower incidence of statistically significant differences between periods meant that retentive properties became less variable, i.e. relatively stable.

Statistical analysis. The mean values and standard deviations were calculated for maximum retentive force. Retentive properties at the beginning and end of fatigue simulation were compared by paired-samples t-test. Multiple comparisons between types of attachments were made by 1-way ANOVA and Scheffe post hoc tests with statistical software package (SPSS ver.11 for Windows, SPSS Inc.). Statistical significance was set at P<0.05.

RESULTS

ANOVA test indicated that statistically significant differences existed among the five attachments before and after fatigue simulation.

Average curves of retentive force changes of overdenture attachments tested are presented in Figure 4. Initially retentive force of attachments was not stable.

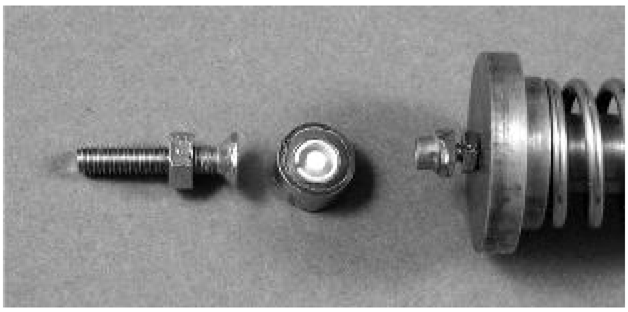

Fig. 2. The tooth (implant) component of the attachment was attached to a jig, while denture component was embedded into metal ring by auto-polymerizing resin (Unifast Trad, GC)

Fig. 3. Specially constructed jig was connected to a load cell of fatigue machine. Demineralized water was warmed up to 37 C by 38 C water circulating outside the bath

Table 3. Determination of minimum number of cycles required to simulate fatigue. Numbers indicate incidence of statistically significant differences detected by paired-samples t-test (P<0.05)

Coparisons	OP	LRP	EW	EO	MF	Total
0-400 vs 400-800	3	2	3	3	1	12
400-800 vs 800-1200	1	0	0	1	0	2
800-1200 vs 1200-1600	1	0	0	0	0	1
1200-1600 vs 1600-2000	0	0	0	0	0	0

Fatigue test revealed 2 distinct groups of attachments. For the first group, the maximum retentive force by 2000th insertion-removal cycle slightly increased (OP). For the second group, there was a sudden decrease in retentive force (LRP, EW, and EO). As expected the magnetic attachment tested (MF) preserved relatively constant maximum retentive force throughout the fatigue testing period.

Absolute and percentage changes in retentive force of overdenture attachments before and after fatigue simulation are showed in Table 2. For all attachments retentive force change before and after fatigue were statistically significant (P<0.05). Unexpectedly, OP has gained approximately 137% of initial retentive force after 2000 cycles. For other types of attachments retentive force after fatigue simulation was from 25% to 98% of initial retention. Magnetic attachments have best fatigue resistance properties - only 2% decrease in retention. While biggest decrease in retentive force was noticed for EO and EW - 75% and 63% respectively. As it can be noticed from standard deviations initial retentive force followed a less stable course to compare with measurements at the end of fatigue simulation. Owing minimum standard deviation magnetic attachments provided most uniform retention.

Comparisons of retentive force means between 0-400 and 400-800, 400-800 and 800-1200, 800-1200 and 1200-1600, and 1200-1600 and 1600-2000 periods allowed calculating number of statistically significant differences for each type of attachment (Table 3). There was a clearly lower incidence of statistically significant differences between 800-1200 and 1200-1600, 1200-1600 and 1600-2000 groups. Thus it was assumed that after 800 insertion-removal cycles the stud attachments obtained a relatively stable retention.

DISCUSSION

Assuming that patients remove overdenture on average tree times a day three in vitro insertion-removal cycles should represent 1 day of wearing a prosthesis. However, disagreement between clinical findings and in vitro fatigue tests indicates that wear cannot be adequately simulated in in vitro studies. It is virtually impossible to follow changes of retentive force of overdenture attachments intraorally during the function [34]. Minimal displacement of overdenture in three dimensions during function and parafunction, insertion and removal of overdenture in para-axial direction, implant angulation, ageing of resilient parts and combinations of these factors were addressed as possible causes of this disagreement [35]. Study simulating functional move-

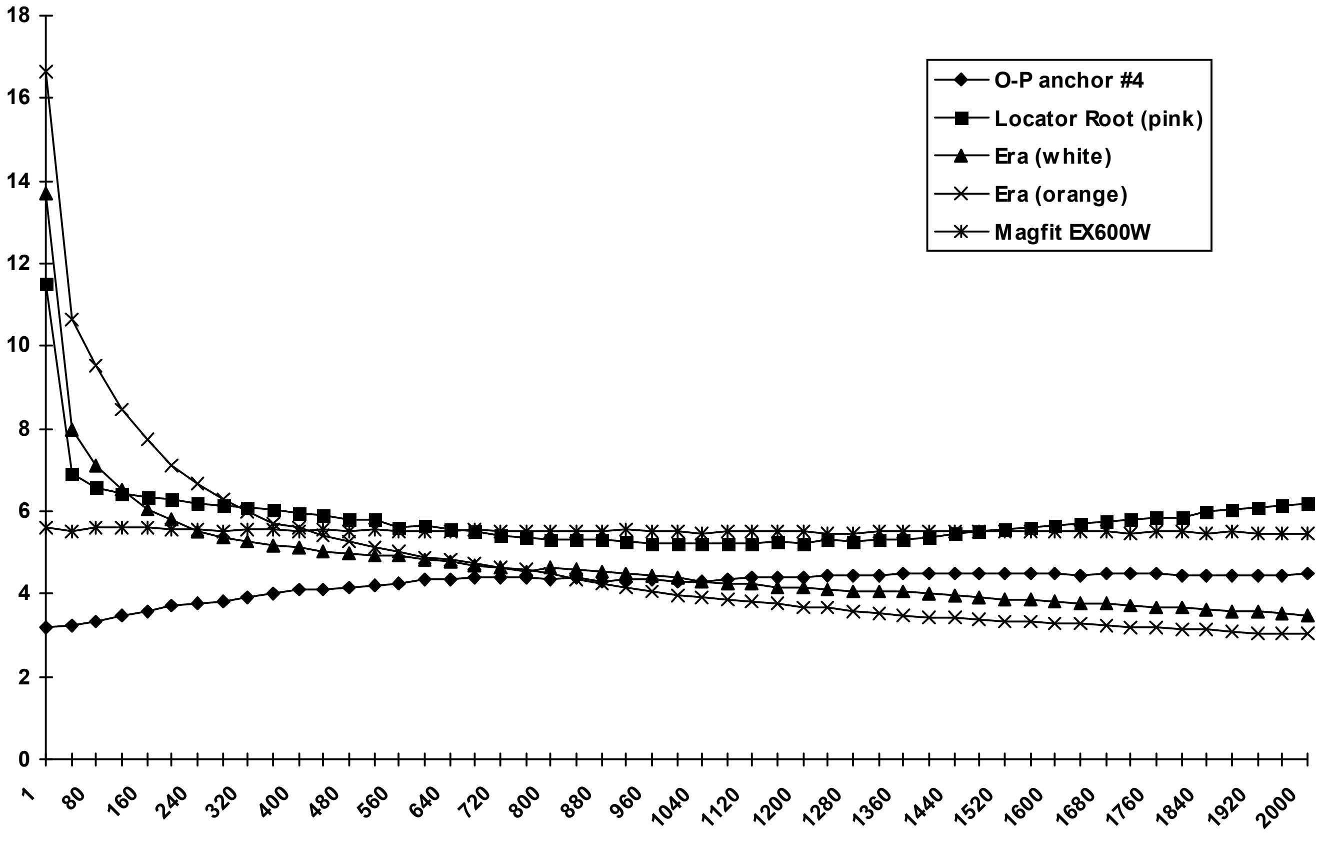

Fig. 4. Average curves representing retentive force (N) changes of OP, LRP, EW, EO and MF during consecutive loading (0-2000 cycles)

ments of mandibular overdenture stated that neither wear of surface nor plastic deformation of the attachment plastic parts occurred significantly under the test conditions [36].

Majority of attachments tested have identical designs for teeth and implant applications. As high congruence exists between in vitro measured retentive properties of overdenture attachments on teeth and implant imitating models, results of this study can be applied to both treatment concepts - tooth-and implant-supported overdentures [37].

Previous studies have measured retentive force of overdenture attachments with a variety of dislodgement speeds ranging from 0.5mm/min to 150 mm/sec [35,38,39]. During a pilot study the tendency was noticed that higher dislodgement speed results in lower measured value of maximum retentive force. The 50 mm/min dislodgement speed was selected for easier comparison of results with those from the majority of previous studies. As the film of saliva between attachment parts acts as a protective layer and lubricant that reduces wear fatigue test was performed in demineralized water for simulating real conditions.

The retentive force measured at the baseline ranged from 3 to 12 N. However, after 2000 insertion-removal cycles it decreased to 3-6 N. Nevertheless a big loss in retention was demonstrated, the amount of retention that is clinically required has not been clearly established. Some authorities stated that a mean load of 3 to 7,5N is needed for the retention of a Class I removable partial denture. Considering that two overdenture attachments would be employed in retaining mandibular overdenture this amount of retention seems to be sufficient. However, besides objective reasons, demand for attachment retention is also dependent on patient requests.

The biggest reduction of retention was noticed in the ERA attachments. Retention measured at the baseline was different that one reported by other study which investigated ERA fatigue behavior [40]. Thought attachment manufacturers state that different color-coded resilient attachments provide different levels of retention, it appears that this is true only considering initial retentive properties. After fatigue simulation there were no significant differences between ERA different colors coded attachments. However, retention at the end of fatigue test corroborated the findings of previous study.

Among stud attachments LRP has best fatigue resistance - approximately 30% of retentive force was lost by the end of fatigue test and it was most retentive (6N). Unexpectedly increase of retention of OP was observed. Thought it was out of the scope for this study to evaluate mechanisms of fatigue, it could be speculated that this could be a result of water absorption of the rubber ring. Also other study investigating surface wear of this type of attachment by means of SEM have found that after fatigue simulation the inner surface of the rubber ring became more smooth as it was before fatigue test [41]. Intimate contact between attachment parts could partially explain increase in retention.

Previous studies have shown that due to the nature of magnetic attraction forces, magnetic attachments show no loss in retention even after 15,000 cycles [37]. However, this study detected significant decrease in retention of magnetic attachments, thought absolute reduction was very small - only 0.1N. As magnetic attachments have very constant retentive properties, the statistically significant difference was detected due to very small standard deviations. Corrosion was attributed to be the main reason of loss of magnetic retention. Still there are other mechanisms of fatigue of magnets. As all new generation magnetic attachments are so-called closed-field systems their retention strongly depends on close contact between magnetic assembly and keeper. Special techniques are used to preserve smoothness of them during fabrication process. It could be hypothesized that as a result of surface wear and scratching the contact between magnetic assembly and keeper becomes imprecise and efficiency of magnetic system is decreased. At the baseline retention provided by magnetic attachment was considerably weaker than that of studs. Yet, at the end of fatigue test only LRP had higher retentive force, while other studs became less retentive.

As initial retention of attachments tends to vary, it was recommended to place and remove attachments around 15 times before overdenture insertion. This will allow an adequate appraisal of the retention of the prosthesis that will be exhibited after a short time of patient service [35]. Furthermore, it might also be advantageous to make the retention force of the attachment during the first denture placement initially at the minimum, and then gradually, but continually, increase it to the desired level. This would facilitate the patients in learning how to handle their overdentures without having to exert an excessive degree of force of effort [42]. Study determining run-in period for overdenture attachments have used only one arbitrarily selected cut-off point. In this study we used 4 cut-of points for dividing all retention values obtained from fatigue test. As the incidence of statistically significant differences was minimal starting from 800 cycles, it was concluded that after 800 insertion-removal cycles all overdenture attachments tested obtained relatively stable retentive properties and their retention should fluctuate minimally further.

CONCLUSIONS

In the light of this study following conclusions can be drawn:

1. Overdenture attachments tend to loose their retention due to fatigue.
2. Initial retention is significantly different from retention after fatigue simulation.
3. Retentive properties of studs are more susceptible to fatigue than that of magnetic attachments.
4. ERA attachments had biggest reduction of retention by the end of fatigue test.
5. Magnetic attachments provide constant retention.
6. Eight hundred cycles are required to achieve relatively stable retention of overdenture attachments.

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