Stomatologija, Baltic Dental and Maxillofacial Journal, 6:85-90, 2004

Retentive and Stabilizing Properties of Stud and Magnetic Attachments Retaining Mandibular Overdenture. An *in vitro* Study

Vygandas Rutkunas, Hiroshi Mizutani

SUMMARY

Objectives: To evaluate and compare retentive and stabilizing properties of stud (ERA Overdenture (orange and white), Locator Root (pink) and OP anchor # 4) and magnetic attachments (Hyperslim 4513, Hyperslim 4013, Magfit EX600W, Magnedisc 500 and Magfit-RK) by measuring maximum retentive force and retentive energy during linear and rotational dislodgments.

Material and methods: Twelve specimens of each type of attachment were used. Linear and 3 types of rotational (anterior, lateral and posterior) dislodgements were performed on one-tooth and mandible-overdenture models, respectively. For each type of dislodgement10 measurements were recorded by universal testing machine (AGS-H, Shimadzu Co., Kyoto, Japan) with 50 mm/min cross head speed. Statistical analysis: one-way ANOVA and Scheffe post-hoc tests ($P<0.05$).

Results: Studs provided higher retention and stability than magnetic attachments. As for rotational dislodgements maximum retentive force of magnetic attachments decreased in following order – anterior > lateral > posterior; whereas of studs – posterior > anterior > lateral. Magnetic attachments had considerably lower retentive energy values for all types of dislodgements.

Conclusions: Retentive properties depend on types of attachment and dislodgment. Stud attachments provide stronger retentive and stabilizing forces than magnetic attachments with all types of dislodgements. Constant retentive properties and low retentive energy of magnetic attachments could assist abutment preservation. Further studies are necessary to clarify range of retention and fatigue behavior of overdenture attachments. Attachments with proper retentive and stabilizing properties should be selected in particular clinical situation.

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

INTRODUCTION

Thought with improvements in public oral health number of edentulous persons has a tendency to decrease, these reductions will not keep in pace with the anticipated increase in the elderly population [1]. Moreover, because of the deferment of edentulousness to older age and additional life expectancy for those over 75 yeas of age, dentists are facing a different challenge to satisfy older-elderly denture wearers with a higher prevalence of chronic disease. Few remaining periodontally compromised teeth or edentulous cases, especially with severely resorbed alveolar ridges, require special approach in order to achieve good long-term clinical results. Traditionally the vast majority of problems arise with a mandibular prothesis, as due to the anatomy of the mandible often they fail to provide adequate support, retention and stability.

The preservation of remaining roots and covering them with denture base has been used since more than a century ago [2]. The overdenture design gained a big popularity and was found highly effective in the mandible. As the root-crown ratio is improved, prognosis of remaining teeth becomes more favorable. Also it appears that the presence of a healthy periodontal ligament maintains alveolar ridge morphology, whereas a diseased periodontal ligament, or its absence, is associated with variable but inevitable time-dependent reduction in residual ridge bulk. Tooth-retained overdenture technique helps reduce the impact of some of complete denture wearing consequences: residual ridge resorption, loss of occlusal stability, undermined esthetic appearance, compromised masticatory function [3].

Edentulous patients have always been a challenge for dental practitioner. That was the prime reason which stimulated development of osseointegrated implants [4]. Treatment considerations for implant retained prosthesis on the mandible appear to be different from that on the maxilla [5]. Basically three concepts are widely used to restore the edentulous mandible: i) implant-supported fixed prosthesis, ii) implant-supported removable overdenture, and iii) combined implant and soft tissue-supported overdenture prosthesis [6]. With a high implant success rates in mandible (97.7-100%) as well as in maxillae (87.5-96.4%) [7] implant-supported (3-6 implants) or implant and soft tissue-supported (1-2 implants) overdentures [8] have offered a good alternative to complete dentures. Implant overdentures are preferred over complete dentures as they permit better biting and chewing, retention and stability, patient satisfaction and maintenance [9]. It appears that retention, stability, and chewing ability improve only slightly with an implant-supported mandibular overdenture as compared with an implant and soft tissue-supported overdenture [10]. Two-implant retained overdentures were found as highly cost-effective treatment. Based on the evidence presented at the McGill symposium (2002) a consensus statement recommending that two-implant mandibular overdentures should replace mandibular conventional dentures as the standard of care for edentulous patients was produced [11].

Different attachment systems are used to retain mandibular overdenture: bars with clips, studs and magnets were reported as viable treatment options. It has been shown that solitary non splinted attachments are less technique sensitive, and easier to clean than bars [12]. Studs and magnets due to their simple application have gained a wide popularity in clinical practice. The patient satisfaction with overdentures depends on multiple factors: patient prefer-

Vygandas Rutkunas - *D.D.S., Center of Prosthodontics, Institute of Odontology, Faculty of Medicine, Vilnius University, Vilnius, Lithuania.*
Hiroshi Mizutani - *D.D.S., PhD, Department of removable prosthodontics, Graduate School, Tokyo Medical and Dental University, Tokyo, Japan.*

Address correspondence to Vygandas Rutkunas, Zalgirio str. 115, 08217 Vilnius, Lithuania. E-mail: vygar@cablenet.lt

ences, chewing comfort, phonetics, esthetics etc. Attachment system was proved as important predictive variable influencing some of the oral function parameters: EMG activity, maximum bite force [13], swallowing threshold, mastication efficiency, stress on alveolar bone, maintenance [14], retention and stability [15]. Whereas implant success and bone resorption [16] were not influenced by attachment type. Investigations have also found that a direct relationship exists between prosthesis retention [17], stability [18] and patient satisfaction.

Retentive and stabilizing quality of particular type of attachment could be characterized by several properties: maximum retentive force, range of retention, retention energy and fatigue behavior [19]. Many previous studies have concentrated on measuring maximum retentive force of overdenture attachments during linear vertical dislodgement [20]. However, in the mouth a restoration is subjected to a variety of displacing forces in differing directions [21]. Therefore it is important to understand retentive and stabilizing properties of attachments during various dislodging patterns. This study examined retention and stability of mandibular overdenture supported by two abutments (either implants or natural teeth).

The aims of the study were:

1. To evaluate retentive properties (maximum retentive force and retentive energy) of overdenture stud and magnetic attachments during linear dislodgement.
2. To evaluate stabilizing properties (maximum retentive force and retentive energy) of overdenture stud and magnetic attachments during 3 types of rotational dislodgments.

MATERIALS AND METHODS

Design

12 specimens of 5 types of magnetic and 4 types of stud attachments were tested (Table 1). Maximum retentive force and retentive energy were measured and recorded 10 times for each specimen by universal testing machine (AGS-H, Shimadzu Co., Kyoto, Japan) and interface software Trapezium 1.22 (Shimadzu Co., Kyoto, Japan) with a 50Hz sampling rate. Before testing each single specimen calibration of universal testing machine was performed. The angulation of abutment, way of dislodgement, dislodgment speed and direction were proved as important factors influencing retention. Therefore in order to avoid confounding of results retentive and stabilizing propereties of attachments were measured under standardized conditions.

Retention is defined as the quality inherent in prosthesis acting to resist the forces of dislodgment along the path of placement [22]. Therefore in order to test retentive properties linear dislodgement slide was performed on one-abutment model (Figure 1) perpendicularly to occlusion plane with a cross-head speed of 50 mm/min. To get more consistent results, prior recording maximum of measurements 10 dislodgement slides were performed.

Stability is defined as the quality of prosthesis to be firm, steady or constant, to resist displacement by functional horizontal or rotational stresses [22]. To evaluate significance of type of the attachment to stability, resistance to rotational dislodgements was tested on mandibular-overdenture model. This permitted evaluation one aspect of stability: resistance to rotational dislodgements, which can occur while masticating sticky food and are paramount complaint of the patients who indicate "lack of stability". 3 types of rotational dislodgments (Figure 2) were performed and evaluated on mandibular-overdenture model: 1) anterior rotational dislodgement – two chains were attached to the hooks on the left and right canines; 2) lateral rotational dislodgement – two chains were attached to the hooks on the left canine and second molar; 3) posterior rotational dislodgement – two chains were attached to the hooks on

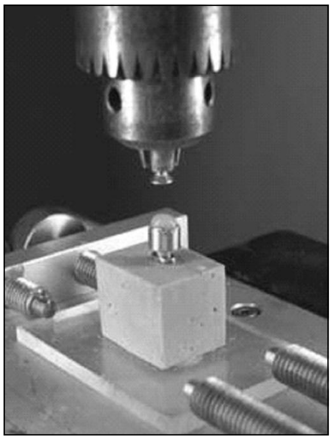


Figure 1. One-tooth model with secured specimen on the table of universal testing machine (AGS-H, Shimadzu Co., Kyoto, Japan).

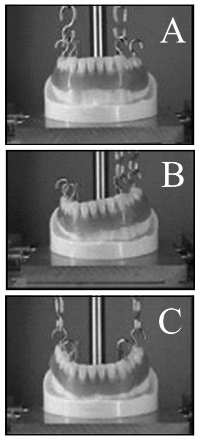


Figure 2. Testing on mandible-overdenture model. Rotational dislodgements: A – anterior; B – lateral; C – distal.

Table 1. Magnetic and stud overdenture attachments tested.

No.	Type	Attachment	Abbreviation	Manufacturer
1	Magnetic attachments	Magnedisc 500	MD	Aichi Steel Corp., Aichi, Japan
2		Magfit EX 600W	MF	
3		Magfit-RK (dome shaped)	RK	
4		Hyperslim 4013	H40	Hitachi metals Ltd., Tokyo, Japan
5		Hyperslim 4513	H45	
6	Stud attachments	O-P anchor #4	OP	Inoue attachment Co., Ltd, Tokyo, Japan
7		Locator Root (pink)	LRP	Zest Anchors, Escondido, CA, USA
8		ERA Overdenture (white)	EW	Sterngold, Attleboro, MA, USA
9		ERA Overdenture (orange)	EO	

the second molars bilaterally. 12 specimens of each type of the attachment were paired randomly into 6 sets and maximum retentive force and retentive energy were measured and recorded.

Specimen preparation

Plastic patterns of O-P anchor males and ERA females were cast from type IV gold alloy (Degulor M, Degussa Dental GmbH&Co. KG, Hanau-Wolfgang, Germany), hardened, pickled in acid solution (Neacid, Degussa Dental GmbH&Co. KG, Hanau-Wolfgang, Germany), finished and polished by sand blasting (50μm glass beads, 0.2 MPa) and silicone points (GC, Tokyo, Japan) under control of microscope (Inoue attachment Co., Ltd, Tokyo, Japan). Implant (radicular) parts of all attachments were centered on heads of non-ferromagnetic screw and glued by epoxy resin glue (Bond Quick 5, Konichi Corp., Osaka, Japan). Minimal thickness of glue aided in orientating attachments parallel to the occlusal plane. Denture parts of attachments were placed on their corresponding parts and embedded into metal rings (7mm radius) by auto-polymerizing resin Unifast Trad (GC, Tokyo, Japan) using brush-dip technique.

One-abutment model fabrication

Abutment model was cast in the shape of canine root, the central part of it was tapped and it was embedded into block of acrylic resin (Ostron II, GC, Tokyo, Japan). Later 1mm thickness of acrylic resin around abutment was removed and replaced by silicone impression material (Exafine, GC, Tokyo, Japan) imitating periodontal ligament. Model was attached to table of universal testing machine (AGS-H, Shimadzu Co., Kyoto, Japan). One part of attachment was secured to abutment by tightening the screw and metal ring containing denture part of attachment was seated on it, following instructions of manufacturers. The denture part was secured to the rod of testing machine by means of auto-polymerizing resin (Unifast Trad, GC, Tokyo, Japan). Period of ten seconds between each measurement aided recovery of resilient parts of studs. To simulate intraoral environment and achieve similar values of frictional force, demineralized water was applied by brush on the surface of attachments.

Mandibular-overdenture model fabrication

In order to evaluate stabilizing forces of attachments, mandibular model and acrylic metal framework-reinforced overdenture were fabricated. Two cast abutments (identical to that used in one-abutment model) were embedded in the region of canines on mandibular model (#552, Nissin Dental Co.Ltd., Kyoto, Japan) with a distance of 26 mm between them. Periodontal ligament was imitated by 1mm thickness of silicone impression material (Exafine, GC, Tokyo, Japan) and mucosa – by 3 mm thickness of silicone material (Fit Checker, GC, Tokyo, Japan) [23]. No undercuts were left on denture bearing area. The acrylic (Acron, GC, Tokyo, Japan) Cr-Co (Biosil-L, Degussa Dental GmbH&Co. KG, Hanau-Wolfgang, Germany) framework-reinforced overdenture fitting mandibular model was fabricated. Four metal hooks were attached symmetrically in the region of both canines and both second molars. Two holes above abutments were prepared in the base of overdenture. One part of attachment was secured to the abutment and other incorporated into the base of overdenture according to the instructions of manufacturer by auto-polymerizing resin (Unifast Trad, GC, Tokyo, Japan).

Statistical analysis

The means and standard deviations were calculated for maximum retentive force and retentive energy. Multiple comparisons were made by one-way ANOVA and Scheffe post hoc tests with SPSS ver.11 for Windows (SPSS Inc., Chicago, IL, USA). Statistical significance was set at $P<0.05$.

Table 2. Maximum retentive force and retentive energy means and standard deviations of overdenture attachments during various dislodgement patterns (bars connect groups with not significant difference $P>0.05$).

	Type	Linear		Anterior		Lateral		Posterior	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD
Maximum retentive force	MD	4.46	0.35	6.71	0.61	2.84	0.36	1.00	0.09
	MF	4.70	0.33	7.18	0.36	3.28	0.28	1.26	0.12
	RK	5.80	0.25	7.67	0.40	4.05	0.48	1.94	0.22
	H40	4.92	0.15	7.75	0.97	3.92	0.53	1.50	0.19
	H45	5.63	0.11	10.59	0.47	4.68	0.29	1.67	0.19
	OP	3.71	0.43	5.44	0.31	3.26	0.33	8.49	0.78
	RLP	10.58	1.24	14.82	2.03	7.65	1.18	14.58	1.69
	EW	9.89	0.98	14.48	0.81	8.85	0.27	15.37	1.14
	EO	10.94	0.76	13.25	1.63	6.12	0.38	16.19	0.38
Retentive energy	MD	0.46	0.06	1.05	0.10	0.74	0.32	1.44	0.18
	MF	0.65	0.07	1.46	0.13	1.56	0.25	2.09	0.18
	RK	0.59	0.05	1.28	0.09	2.11	0.14	2.79	0.26
	H40	0.65	0.05	1.29	0.14	1.40	0.22	1.85	0.18
	H45	0.98	0.03	2.00	0.22	1.67	0.16	2.48	0.20
	OP	3.11	0.59	4.29	0.41	7.85	1.25	12.14	1.28
	RLP	2.78	0.45	4.76	0.82	5.82	0.76	8.74	1.24
	EW	3.75	0.55	7.16	0.32	7.82	0.51	12.83	0.46
	EO	5.11	0.58	6.57	0.94	9.80	0.78	13.27	0.40

RESULTS

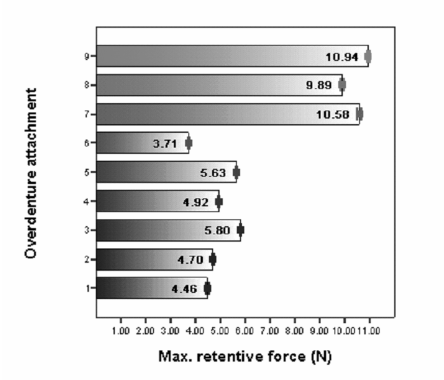
Means and standard deviations of maximum retentive force and retentive energy of 9 types of overdenture attachments are presented in Table 2 and Figure 3. Stud and magnetic attachments had distinct retentive and stabilizing properties. Majority of stud attachments with an exception of OP had maximum retentive force higher than magnetic attachments. EO had highest retentive properties, while stability with anterior rotational dislodgement was best provided by RLP and EW, with lateral – by EW and posterior – by EO attachments. Magnetic attachments with larger diameter (containing more magnetic material) tended to provide higher retention and stability. Among magnets most retentive and stabilizing were RK and H45. Maximum retentive force in the group of magnetic attachments decreased remarkably during posterior rotational dislodgement. Thus, indicating that magnetic attachments have lower stabilizing properties with this type of denture movement. With other types of dislodgements maximum retentive force of magnetic attachments thought higher was still approximately two times lower to compare with studs. Statistically insignificant differences were mainly limited to the group of magnetic attachments. Magnetic attachments had very constant retentive and stabilizing properties (low standard deviation). Retentive energy was considerably higher in the group of stud attachments (2.78-13.27Nmm) to compare with magnetic ones (0.46-2.79Nmm) with all types of dislodgements. Retentive energy represents integrated aspect of resistance to dislodgement. Attachments owing higher maximum retentive force did not always have higher retentive energy.

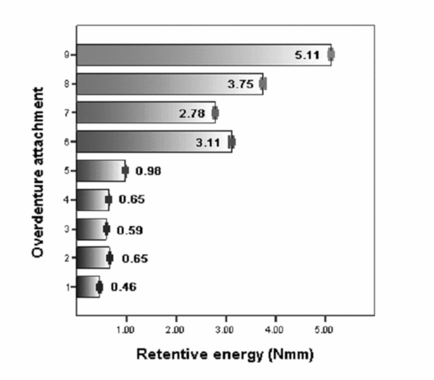
DISCUSSION

Correlations between clinical measures and the condition reported by the patient are often nonsignificant [24]. However evaluation of technical aspects is highly appreciated as it is easy controlled and objective instrument. Moreover retention and stability of removable denture are addressed as important factors having effect on patient preference and satisfaction. Technical quality of prosthesis was also reported as significantly correlating to patient satisfaction, therefore straightforward techniques such as studs or magnets are appreciated. As in the literature reported retentive forces of attachments used with natural abutments are well comparable with those for use with implants [20] results of this study are applicable to both natural teeth and implant supported mandibular overdentures.

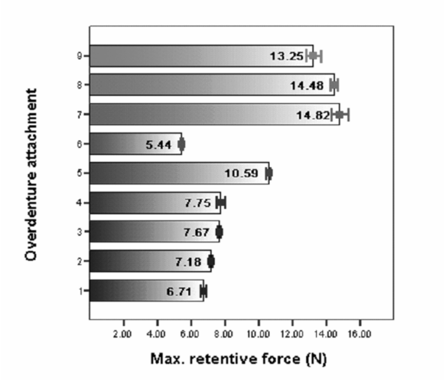
Figure 3. Maximum retentive force and retentive energy of overdenture attachments.

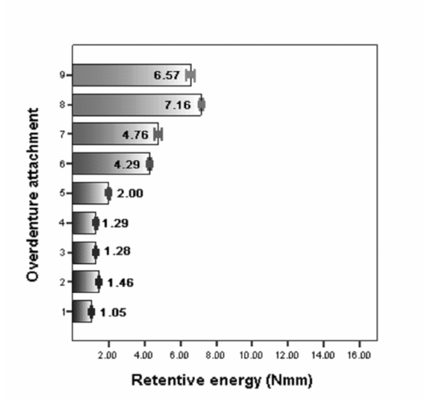
Maximum retentive force	Retentive energy



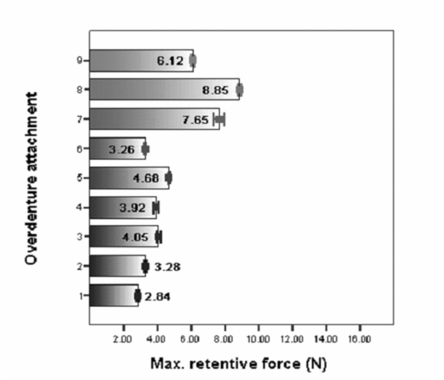


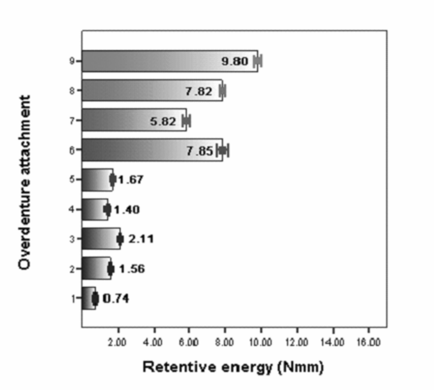
A



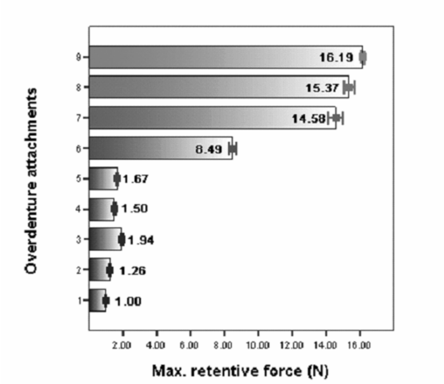


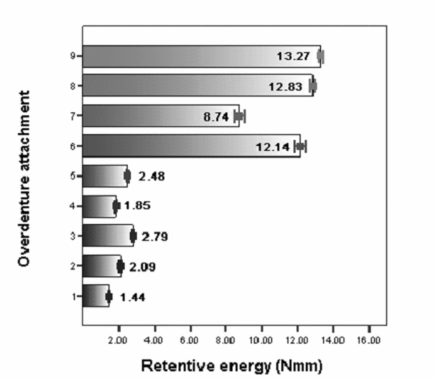
B





C





D

A – linear, B – anterior rotational, C – lateral rotational, D – posterior rotational dislodgements.
1 - Magnedisc 500, 2 - Magfit EX 600W, 3 - Magfit-RK, 4 - Hyperslim 4013, 5 - Hyperslim 4513, 6 - O-P anchor #4, 7 - Locator Root (pink), 8 - ERA Overdenture (white), 9 - ERA Overdenture (orange).

The aim of the study was to give insight into retentive and stabilizing properties of overdenture stud and magnetic attachments. As there are many factors contributing to overdenture retention and stability intraorally, *in vitro* study design permitted isolated evaluation of attachment system influence on retention and stability. However it is impossible to reproduce precisely intraoral displacement patterns. Unlike with an *in vitro* model parts of attachment do not separate completely during function. Retentive and stabilizing properties also depend on dislodgement speed. 50 mm/min dislodgement speed was selected in order to compare results with other studies, as majority of them have used similar testing conditions [25, 26]. Thought overdentures generally do not have a distinct path of insertion or removal, retentive properties were tested under standardized conditions during linear dislodgement in order to get more constant results. Stability of removable prosthesis implies far more than resistance to rotational dislodgements. Stability in horizontal direction is a significant variable too with residual ridges playing a chief role. Nevertheless owing high maximum retentive force retentive device would serve little clinical purpose if this force will fall to zero with a separation of 100μm. Similarly it would not be useful if due to fatigue it will lose its retention after few weeks. Therefore range of retention and fatigue behavior are critical characteristics. As it was shown by studies, fatigue behavior is difficult to simulate and results of *in vitro* studies poorly represent clinical performance of attachments. In this study, due to limitations of testing equipment and software the range of retention could not be recorded automatically, for that reason in order to avoid measurement error it was not estimated.

The results were in line with previous studies which tested maximum retentive forces of stud attachments [15]. However retentive and stabilizing properties of magnetic attachments used in this study have never been evaluated before. Few studies compared clinical performance of magnetic and mechanical attachments [27, 28]. They noted demand for higher stability in the group of magnetic 2 implant-supported overdentures which was significantly different from that in the group of ball or bar attachment. Although magnetic attachments used in our study were different it is possible to justify these results as stabilizing forces of magnets particularly with posterior rotational dislodgement were lower as compared to that of studs. This can be explained by higher profile of studs and “blocking” action during posterior rotational dislodgement. Yet retention and resistance to anterior and lateral rotational dislodgements of magnetic attachments can be considered as comparable to studs, as retentive properties of mechanical attachments in contrast to magnetic ones tend to decrease considerable with number of insertion-separation cycles [20].

Stud and magnetic attachments were found to have different gradient of stabilizing properties. For majority of studs stabilizing forces measured during 3 types of rotational dislodgement decreased in following order: posterior > anterior > lateral; whereas for magnetic attachments: anterior > lateral > posterior. These results can give a hint that in clinical situations where displacement forces are located far away from fulcrum (abutment) magnetic attachments may fail to provide adequate stability.

Magnetic attachments are far not new dental devices. They are highly appreciated as having small dimensions, low profile, constant retentive properties and favorable load distribution. With natural abutments degree of stability can be easily prescribed using concept “retention without reciprocation”, i.e. establishing desired height and taper of coping [29]. Up to date measurements of retentive energy have never been reported in scientific papers. This study found that magnetic attachments had significantly lower retentive energy as to compare with studs. It means that less energy is required to dislodge attachment parts, yet fewer loads are transferred to abutments. It could be hypothesized that magnetic attachments could be attachment of choice when abutments offer limited support and have not favorable prognosis. In addition, during seating corresponding parts of overdenture magnetic attachments have no contact, thus preventing abutments from overloading. Decreased manual dexterity and multiple abutments could be an indication for using magnetic devices. Wear and subsequent corrosion were reported with magnetic attachments [30]. However micro-laser welding technique and application of ferromagnetic stainless steel have claimed to solve these problems.

Though empirically based opinion about preferred retentive force (20 N) and range of retention (200-300μm) in edentulous mandible exist, it is impossible to delineate ideal retentive and stabilizing properties of overdenture attachments as different clinical situations require individual approach. Selection of attachment type should result from considerations of patient preference, masticatory function, maintenance, abutment loading, retention and stability.

CONCLUSIONS

This *in vitro* study tested retentive and stabilizing properties of 5 types magnetic and 4 types stud overdenture attachments. Measurements of maximum retentive force and retentive energy were performed during linear and 3 types of rotational dislodgements. Within the parameters of this study design, following conclusions may be made:

1. Stud and magnetic overdenture attachments have different retentive and stabilizing properties.
2. Stabilizing properties depend on dislodgement pattern.
3. Stud attachments provide higher retentive and stabilizing forces than magnetic attachments with all types of dislodgements.
4. Magnetic attachments have retentive and stabilizing forces approximately two times weaker. With posterior rotational dislodgement they decrease remarkably.
5. Constant retentive properties and low retentive energy of magnetic attachments could assist abutment preservation.
6. Further studies are necessary to clarify range of retention and fatigue behavior of overdenture attachments.
7. Understanding of retentive and stabilizing properties could aid in proper selection of overdenture attachment type.

ACKNOWLODGEMENTS

The authors wish to thank Hitachi Metals Ltd. And Aichi Steel Corp. for donating magnetic attachments.

REFERENCES

1. Douglass CW, Shih A, Ostry L. Will there be a need for complete dentures in the United States in 2020? *J Prosthet Dent* 2002; 87(1):5-8.
2. Brewer AB, Morrow RM, editors. Overdentures. 2nd ed. Missouri: Mosby; 1980.
3. Zarb GA, Bolender ChL, Carlsson GE. Boucher's prosthodontic treatment for edentulous patients. 11th edition, 1997.
4. Branemark PI, Hansson BO, Adell R, et al. Osseointegrated implants in the treatment of the edentulous jaw. Experience from a 10-year period. *Scand J Plast Reconstr Surg Suppl* 1977; 16: 1-132.
5. Chan MF, Narhi TO, de Baat C, Kalk W. Treatment of the atrophic edentulous maxilla with implant-supported overdentures: a review of the literature. *Int J Prosthodont* 1998; 11(1): 7-15.
6. Zitzmann NU, Marinello CP. Decision-making and treatment planning in the edentulous mandible restored with fixed and removable implant prostheses. *World Dent* 2001;1(2); available at www.worlddent.com.
7. Goodacre CJ, Bernal G, Rungcharassaeng K, Kan JY. Clinical complications with implants and implant prostheses. *J Prosthet Dent*2003 Aug;90(2):121-32.
8. Simon H, Yanase RT. Terminology for implant prostheses. *Int J Oral Maxillofac Implants* 2003; 18(4): 539-43.
9. Bakke M, Holm B, Gotfredsen K. Masticatory function and patient satisfaction with implant-supported mandibular overdentures: a prospective 5-year study. *Int J Prosthodont* 2002 ; 15(6): 575-81.
10. Sadowsky SJ. Mandibular implant-retained overdentures: a literature review. *J Prosthet Dent* 2001; 86(5): 468-73.
11. The McGill consensus statement on overdentures. *Quintessence Int* 2003; 34(1): 78-9.
12. Cune MS, de Putter C, Hoogstraten J. Treatment outcome with implant-retained overdentures: Part II—Patient satisfaction and predictability of subjective treatment outcome. *J Prosthet Dent* 1994 ; 72(2): 152-8.
13. van Kampen FM, van der Bilt A, Cune MS, Bosman F. The influence of various attachment types in mandibular implant-retained overdentures on maximum bite force and EMG. *J Dent Res* 200; 81(3): 170-3.
14. Gotfredsen K, Holm B. Implant-supported mandibular overdentures retained with ball or bar attachments: a randomized prospective 5-year study. *Int J Prosthodont* 2000; 13(2):125-30.
15. Petropoulos VC, Smith W. Maximum dislodging forces of implant overdenture stud attachments. *Int J Oral Maxillofac Implants* 2002;17(4): 526-35.
16. von Wowern N, Gotfredsen K. Implant-supported overdentures, a prevention of bone loss in edentulous mandibles? A 5-year follow-up study. *Clin Oral Implants Res* 2001; 12(1): 19-25.
17. Naert I, Quirynen M, Theuniers G, van Steenberghe D. Prosthetic aspects of osseointegrated fixtures supporting overdentures. A 4-year report. *J Prosthet Dent* 1991; 65(5): 671-80.
18. Feine JS, de Grandmont P, Boudrias P, Brien N, LaMarche C, Tache R, Lund JP. Within-subject comparisons of implant-supported mandibular prostheses: choice of prosthesis. *J Dent Re* . 1994; 73(5): 1105-11.
19. Rutkunas V, Mizutani H, Nakamura K, Kotake M, Ishikawa S. Comparison of retentive force properties of different overdenture stud attachments. In: Proceedings of the Thirteenth Meeting of Japanese Society of Magnetic Applications in Dentistry, Nov 22-23, 2003, Yokohama, Japan.
20. Setz I, Lee SH, Engel E. Retention of prefabricated attachments for implant stabilized overdentures in the edentulous mandible: an in vitro study. *J Prosthet Dent* 1998; 80(3): 323-9.
21. Preiskel HW. Fundamentals of mechanical and magnetic attachments. In: Proceedings of the Sixth International Symposium on Magnetic Dentistry, Oct 19-20, 2002, Yokohama, Japan
22. The Academy of Prosthodontics. Glossary of Prosthodontic Terms. 7th edition. *J Prosthet Dent.* 1999; 81(1): 39-111.
23. Mizuuchi W, Yatabe M, Sato M, Nishiyama A, Ohyama T. The effects of loading locations and direct retainers on the movements of the abutment tooth and denture base of removable partial dentures. *J Med Dent Sci* 2002; 49:11-18.
24. Feine JS, Carlsson GE, editors. Implant Overdentures. The Standard of Care for Edentulous Patients. Carol Stream (Il):Quintessence Publishing Co. Inc; 2003.
25. Besimo CE, Guarneri A. In vitro retention force changes of prefabricated attachments for overdentures. *J Oral Rehabil* 2003 ; 30(7): 671-8.
26. Gamborena JI, Hazelton LR, NaBadalung D, Brudvik J. Retention of ERA direct overdenture attachments before and after fatigue loading. *Int J Prosthodont* 1997;10(2): 123-30.
27. Davis DM, Packer ME. Mandibular overdentures stabilized by Astra Tech implants with either ball attachments or magnets: 5-year results. *Int J Prosthodont* 1999; 12(3): 222-9.
28. Naert I, Gizani S, Vuylsteke M, Van Steenberghe D. A 5-year prospective randomized clinical trial on the influence of splinted and unsplinted oral implants retaining a mandibular overdenture: prosthetic aspects and patient satisfaction. *J Oral Rehabil.* 1999 Mar;26(3):195-202.
29. Mizutani H. Evaluation of Removable Partial Dentures. *The Nippon Dental Rev* 1995.
30. Riley MA, Williams AJ, Speight JD, Walmsley AD, Harris IR. Investigations into the failure of dental magnets. *Int J Prosthodont* 1999; 12(3): 249-54.

Received: 02 09 2004
Accepted for publishing: 20 09 2004