

Evaluation of retentive force of attachment systems for overdentures retained by one or two implants

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ABSTRACT

Objective: Single implant-retained overdentures are an appealing option for rehabilitation, but the retentive force of attachments in this setting has yet to be determined.

Methods: Three attachment systems (ERA, O-Ring, and Ball Attachment), using components made from different materials (plastic and metal), were tested under two different support conditions (single-implant or two-implant). Under irrigation, the systems were subjected to a series of simulated insertion-removal cycles. Maximal retention values were obtained before testing and after 3,240 cycles on a universal testing machine (cross-head speed of 0.5 mm/min). Student's *t*-test for independent samples was used for statistical analysis ($P < 0.05$).

Results: Tensile strength of the O-Ring and Ball Attachment systems did not show significant changes after mechanical cycling (with one or two implants), while the ERA system showed significant reductions at cycles 2,160 and 3,240 (in the single-implant and in the two-implant specimens) as compared with the other cycles.

Conclusion: Single-implant support for mandibular overdentures can be an alternative for the oral rehabilitation of fully edentulous patients, providing greater simplicity, lower costs, and similar retentive strength as compared to two-implant overdentures, improving the user's quality of life. The tested systems meet the retentive needs of removable prosthodontic appliances, regardless of the number of supporting implants.

Keywords: Dental Implants; Complete Denture; Overdenture; Single Implant.

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Avaliação da força de retenção de sistemas de encaixe para overdentures retidas por um ou dois implantes

RESUMO

Objetivo: Overdentures retidas por um único implante são uma opção reabilitadora, entretanto a força de retenção dos encaixes nessa condição ainda não foi estabelecida.

Métodos: Três sistemas de encaixe (ERA, O-Ring e Ball Attachment), que utilizam diferentes materiais para retenção (plástico e metal), foram testados sob diferentes condições de suporte para uma overdenture (implante único ou dois implantes). Os sistemas de encaixe foram submetidos a um ensaio simulando ciclos de inserção-remoção da prótese. Valores máximos de retenção foram obtidos antes e após a realização de 3.240 ciclos, em uma máquina de ensaios universal, com velocidade de 0,5 mm/min. Os resultados foram submetidos ao teste *t* de Student para amostras independentes ($P < 0.05$).

Resultados: Os valores de força de retenção dos encaixes O-Ring e Ball Attachment não apresentaram diferença estatística após ciclagem mecânica (com 1 ou 2 implantes), enquanto que o sistema ERA apresentou redução significativa nos ciclos 2.160 e 3.240 (com 1 e 2 dois implantes) quando comparado aos demais ciclos.

Conclusões: Overdentures mandibulares retidas por implante único podem ser uma alternativa para a reabilitação de pacientes edêntulos, proporcionando maior simplicidade, menor custo e retenção semelhante às overdentures retidas por 2 implantes, com consequente melhora na qualidade de vida. Os sistemas de encaixe avaliados apresentaram a retenção necessária para overdentures, independentemente do número de implantes.

Palavras-chave: Implantes Dentários; Prótese Total; Sobredentadura; Implante Único.

INTRODUCTION

The use of osseointegrated implants to support dental prostheses has proven efficacy (1). Implant-retained mandibular overdentures improve quality of life for edentulous patients, obtained by greater retention of complete dentures (2).

Compared to implant-supported fixed complete dentures, overdentures provide advantages that include lower treatment cost, possibility of removal for care and cleaning, and, in specific cases, clearer speaking, in addition to factors that contraindicate placement of a greater number of implants, such as severe bone resorption, mandibular atrophy, and poor bone quality (3).

Currently, the standard implant-based treatment recommended for edentulous patients involves placement of two implants into the alveolar bone in the anterior region of the mandible (4). Several studies have evaluated the retentive force of these systems, whether isolated or using bar-and-clip systems (5), all-plastic attachments (6), both plastic and metal components (3), and among different attachment systems (7,8), and have demonstrated their efficiency.

With advances in this predictable treatment modality, some authors have suggested that similar outcomes can be obtained using only one implant placed in the anterior region of the mandible (9-11). Walton et al. (12) conducted a clinical assessment of the performance of mandibular overdentures retained by a single midline implant in terms of

patient satisfaction, component costs, and maintenance sessions for 1 year after placement, as compared with conventional treatment. According to the authors, a single-implant solution for overdenture retention and stabilization was as satisfactory as two implants, requiring the same maintenance but with reduced operative time and cost. In another clinical study, Cordioli et al. (13) reported improvement in comfort and masticatory function in 21 patients treated with the single-implant approach.

This is an affordable and relatively simple treatment option, with the advantage that implant parallelism is less of a concern (14). Therefore, it is a promising restorative treatment modality, and is relevant from a social standpoint for rehabilitation of low-income patients (15,16). It is known that attachments must have a retentive force of at least 5N to keep prosthetics in place during function (17). However, daily use, the oral environment, and parafunctional activities may affect the retentive capacity of attachments.

Within this context, the present *in vitro* study sought to compare the resistive force and fatigue resistance of three attachment systems in single-implant and two-implant conditions. The null hypothesis was that there would be no differences among the three attachment systems in the two simulated conditions.

MATERIAL AND METHODS

Three types of overdenture attachments were selected: ERA (APM – Sterngold, Attleboro, MA, USA); O-Ring (3i, Palm Beach Gardens, FL, USA); and Ball Attachment (NobelBiocare, Yorba Linda, CA, USA). Four specimens of each system were fabricated, in two conditions (two-implant and single-implant), as shown in Table 1.

TABLE 1 – Trade name, manufacturer, and components of tested attachment systems and number of specimens used in analysis.

Trade name	Manufacturer	Components (1 implant)	Components (2 implants)	No. of specimens
ERA	APM–Sterngold, Attleboro, MA, USA	1 abutment ^a , 1 white nylon ^b	2 abutments ^a , 2 white nylon ^b	4
O-Ring	3i, Palm Beach Gardens, FL, USA	1 abutment ^a , 1 black nylon ^b	2 abutments ^a , 2 black nylon ^b	4
Ball Attachment	Nobel Biocare, Yorba Linda, CA, USA	1 abutment ^a , 1 gold “female” ^c	2 abutments ^a , 2 gold “females” ^c	4

^a Abutment dimensions: height 2 mm, 0°.

^b Female with lowest retentive force in each system.

^c Only female connector available for this system; retention was standardized as one full turn of provided driver.

Two cylinders (height 20 mm, diameter 35 mm) were made from autopolymer acrylic resin (Orto Clas – Artigos Odontológicos Clássico Ltda., São Paulo, SP, Brazil). Two implants (ICE, 3i, Palm Beach Gardens, FL, USA) were embedded into one cylinder,

22 mm apart (5). A single implant was embedded into the other cylinder (Figure 1).

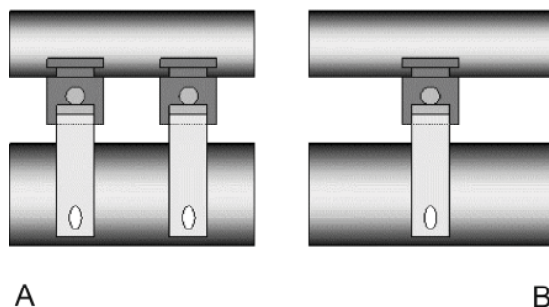


FIGURE 1 – A) Two-implant specimen: acrylic resin base containing two implants and abutments, set 22 mm apart, and counterpart acrylic resin analog containing retentive components; B) Single-implant specimen: acrylic resin base containing one implant and abutment and counterpart acrylic resin analog containing single retentive component.

Briefly, the components necessary for single-implant and two-implant retention – a pair of components from each system for two-implant analogs and a single component from each system for the single-implant analogs – were installed onto the resin cylinders and assayed on a universal testing machine.

The least retentive abutment of each system was selected: namely, the white component of the ERA system, the black component of the O-Ring system, and the gold component (the only one available) of the Ball Attachment system. Retention of the gold component of the Ball Attachment was standardized by activation (one full turn) using the tool provided.

The corresponding retention components of each system were embedded in another autopolymer acrylic resin analog (height 2 cm, diameter 3.5 cm), made to simulate the base of a complete denture (Figure 1). During testing, insertion-removal motions were performed along the implant axis in standardized fashion.

The mechanical cycling test was performed on a VERSAT 502M universal testing machine (Panambra Industrial e Técnica S.A., São Paulo, SP, Brazil), with an HBM S40/50kg load cell (HBM Inc., Darmstadt, Germany). The attachment systems were subjected to 3,240 insertion-removal cycles, to simulate 3 years of use (removal three times daily for cleaning). The motor speed was set at 32rpm and the test performed under constant irrigation with artificial saliva (Salivan, Aspen Farmacêutica S/A, São Paulo, SP, Brazil).

The retentive force of the attachment was measured before the start of mechanical cycling (0 cycles) and after 3,240 cycles (36 months). Maximum force was reached at the time of separation between the abutment and retainer of the attachment system, at a crosshead speed of 0.5 mm/min.

Student's *t*-test for independent samples was used for statistical analyses. The significance level to reject the null hypothesis was set at $P < 0.05$. For each attachment

system, we compared percent retention loss in the conventional (two-implant) overdenture model and in the single-implant model.

RESULTS

As shown in Table 2, mechanical cycling did not cause significant changes in the tensile strength of the O-Ring and Ball Attachment systems, whether with one or two implants. With the ERA system, significant reductions in tensile strength occurred at cycles 2,160 and 3,240, both in the single-implant and in the two-implant specimens, as compared with the values measured during other cycles.

TABLE 2 – Mean (standard deviation) tensile strength values (N).

Cycle / system	0	180	540	1080	2160	3240
ERA						
1 implant	13.37 (1.6)	10.67 (0.9)	10.12 (1.5)	9.22 (0.8)	7.85 (1.1) ^a	7.02 (1.1) ^a
2 implants	20.75 (3.3)	19.00 (2.1)	18.00 (2.3)	16.25 (2.2)	14.5 (2.6) ^b	14.0 (1.8) ^b
O-Ring						
1 implant	9.2 (3.2)	8.27 (2.7)	8.37 (2.1)	7.85 (2.0)	7.2 (1.2)	7.27 (1.1)
2 implants	13.75 (0.9)	13.50 (0.5)	13.50 (0.6)	13.00 (0.8)	12.75 (1.9)	11.75 (1.5)
Ball Attachment						
1 implant	23.87 (4.4)	25.82 (3.4)	25.65 (3.1)	22.57 (3.9)	21.22 (6.3)	19.12 (6.8)
2 implants	42.75 (0.9)	43.75 (3.4)	43.75 (3.4)	44.25 (3.3)	40.75 (4.6)	44.75 (7.1)

Lowercase letters in rows (ERA system) represent statistically significant differences in relation to other cycles.

Analysis of the results showed that the percent mean reduction of retentive force with the ERA system was 47.4% for single-implant specimens and 31.8% for two-implant specimens. The O-Ring system exhibited reductions of 17.1% and 17.6% respectively under the same conditions. The Ball Attachment system exhibited an 18.2% reduction in single-implant specimens and, unlike the other systems, a 4.5% increase in retentive force in the two-implant specimens.

No component fractures occurred during testing.

DISCUSSION

The null hypothesis that there would be no statistically significant differences among the tested attachment systems under the two study conditions was rejected. The ERA attachment system exhibited significantly lower retentive force after simulation of 3 years' usage. Conversely, the O-Ring and Ball Attachment exhibited no significant differences in retentive force after 3,240 cycles.

In addition to exhibiting a decrease in retentive force after mechanical cycling, the ERA attachment system also showed the highest rate of decline in retention of its components. Similar results were reported by Gamborena et al. (18), who found an 85% reduction in the retentive force of the components of this system. According to the authors, this may have occurred due to permanent deformation of the plastic components, as shown under microscopic analysis. In the present study, the greater reduction observed in single-implant specimens may be attributable to greater load.

In all systems, the retentive force values obtained after mechanical cycling exceeded the minimum level required to keep an overdenture in place, which is 5 N (17). Bearing this in mind, the ERA system may be deemed appropriate for use (whether supported by one or two implants) as long as the patient does not require particularly strong retention (7).

According to several studies, all attachment systems exhibit some wear or deformation after a certain number of cycles and when under functional loading, which may be due to friction between the retaining abutment and its counterpart (19). Similar findings were reported by Epstein et al. (20).

With the O-Ring system, single-implant and two-implant specimens exhibited the same reduction in retentive force, which was less than that observed with the ERA system, although the difference was not significant. The O-Ring system uses a rubber O-ring, which passes over the largest diameter of the retaining abutment and is then trapped below it, to retain the denture. As this component is highly flexible, it exhibits massive elastic deformation and no plastic deformation, which leads to a lesser decrease in retentive force (21).

Finally, in the Ball Attachment group, there was a decrease in retentive force for single-implant specimens and a minor increase in retentive force for two-implant specimens, with no significant difference. The other tested systems had metal abutments and plastic retentive components, whereas the Ball Attachment system has all-metal components. Therefore, during the mechanical cycling test, these components were subjected to repetitive strain, causing permanent deformation. This concept of fatigue may explain the increase in retentive force values (in two-implant specimens) followed by a reduction in these values (in single-implant specimens), with no significant differences (3).

Clinical studies have shown that single-implant support for mandibular overdentures can be an alternative for oral rehabilitation of fully edentulous patients, with consequent improvement in user quality of life (16). Cordioli et al. (22), found insignificant marginal bone loss, improved comfort and oral function, and no treatment failures over a 5-year observation period; treatment was comparable to overdentures supported by two implants.

Krennmair et al. (23) found that single-implant anchorage led to significant improvement in subjective patient satisfaction and to a reduction in commonly reported symptoms. Patients with single-implant-retained overdentures found evidence of improved quality of life and masticatory function.

Liddelow & Henry (24) studied the use of single implant-supported overdentures for rehabilitation of elderly patients with poor retention and phonetic problems, and found a significant increase in patient satisfaction levels.

The number of cycles used in the present study (3,240) simulated 3 years of usage. Other studies have employed varied cycle counts, including 10,000 cycles (19), 5,500 cycles (5,18), and 3,000 cycles (25).

Prefabricated attachments for implant-supported overdentures exhibit major variation in retentive force values (7). Furthermore, the wide range of commercially available brands and models and the broad variability in study methods preclude direct comparison with other investigations. Therefore, further studies are required, as the oral milieu, composition of saliva, temperature, parafunctional habits, and angulation of abutments are all factors that may influence outcomes. Evidently, the conditions under which this study was conducted are distinct from clinical practice, which constitutes a limitation. Nevertheless, our results are valid and significant.

CONCLUSION

Within the limitations of the present study, we conclude there were no significant differences in percent wear among the different overdenture groups, whether supported by a single implant or by two implants. All systems met the basic retention needs of overdentures, whether supported by a single implant or by two implants.

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