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Retention and postinsertion maintenance of bar-clip, ball and magnet attachments in mandibular implant overdenture treatment: an *in vivo* comparison after 3 months of function

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Abstract: It could be hypothesised that attachments, which provide more retention against vertical and horizontal dislodgement, will be associated with more favourable parameters of oral function. This *in vivo* study is designed to provide data regarding initial retention force, loss of retention force after 3 months of function and postinsertion maintenance and complications associated with the use of magnet, bar-clip and ball attachments in mandibular overdenture treatment. Eighteen edentulous subjects received two permucosal implants in the inter-foramina region of the mandible, a new denture and three successive suprastructure modalities (magnet-, bar-clip and ball attachments). The retention force of the attachments at baseline and after 3 months was measured in a standardised way. The amount and type of postinsertion maintenance that was related to the attachment were evaluated. No differences in retention force at baseline and after 3 months of loading were observed for all three attachment types. The mean retention forces of magnet attachments, bar-clip attachments and ball attachments were 8.1, 31.3 and 29.7 N respectively. Functional maintenance complications related to the attachments were predominantly observed in 11/36 magnet attachments. Functional problems in the ball attachment group were relatively rare, easily manageable and seen in 4/36 attachments. The bar-clip attachments exhibited no maintenance problems at all.

Introduction

It is well documented that implant-overdenture treatment in mandibular atrophy is an effective treatment modality. Treatment effects include improvement in oral function and patient satisfaction, in conjunction with a high implant success rate (Burns et al. 1995b; Tang et al. 1997; Naert et al. 1998). Various attachment types can be employed, basically splinting (bar-clip constructions with various bar-shape designs) or not splinting the implants (various ball-type attachments, magnet attachments and attachments with telescopic copings). In a nationwide study in the Netherlands, involving 5410 edentulous patients, bar-clip attachments were used in approximately 80% of all cases (Cune et al. 1995). This attachment type seems popular, but the rationale for dentists to choose a particular type of attachment in mandibular overdenture treatment remains unknown.

Even though prosthodontists seem to prefer splinting the implants by means of a bar-clip construction, ball and magnet

attachments offer some potential advantages. Incorporating these attachments in a denture is less time consuming, which in addition to the lower costs of components makes their use cheaper when compared to bar-clip attachments. Furthermore, nonsplinted constructions facilitate easy cleaning. In addition, nonaxial forces (horizontal and oblique) are of some concern because they lead to higher peak stresses around the implant when compared to axial (vertical) forces (Ciftci & Canay 2000). Nonrigid attachments such as magnet attachments are associated with a lower level of implant moment loading (Heckmann et al. 2001) because the magnetic field does not resist horizontal forces.

Another aspect that could influence the choice of suprastructure type is the amount of maintenance required. Potential complications with attachments in mandibular overdenture treatment include loosening or breakage of clips or ball matrices, corrosion of magnets, loss of retention of clips and ball matrices and loosening of fixation screws of the bar or ball (Walton & MacEntee 1994; Davis et al. 1996; Davis & Packer 1999; Naert et al. 1999; Riley et al. 1999; Walton et al. 2002).

With respect to the issues mentioned above, results from clinical studies in which various attachments are compared seem to indicate that clinical results are excellent, irrespective of the type of attachment that is employed. However, there is only limited, sound scientific information available with respect to variation in oral function among overdentures with various attachment types (Feine et al. 1994; Fontijn-Tekamp et al. 1998; Tang et al. 1999; van Kampen et al. 2002). Although the maximum bite force did not differ among the attachment types in our previous paper, one might expect that differences in mechanical properties among attachment types may result in differences in other parameters of oral function, such as muscle activity during chewing, swallowing threshold and chewing efficiency, and also in parameters such as patient satisfaction and choice of attachment type (van Kampen et al. 2002). It could be hypothesized that attachments, which provide more retention against vertical and horizontal dislodgement, will be associated with more favourable parameters of oral function, patient satisfaction and choice of attachment type. To investigate this hypothesis, a study was designed in which various attachment types were compared with respect to aspects of oral function. For this purpose, the amount of retention that various attachment types provide had to be determined *in vivo*.

The present study is designed to provide such data regarding initial retention force, loss of retention force after 3 months of function and postinsertion maintenance and complications associated with the use of bar-clip, ball and magnet attachments in mandibular overdenture treatment.

Material and methods

Patient population

Eighteen edentulous patients from the Royal Dutch Army and Air Force participated in this randomised crossover clinical trial. They were referred to the Centre for Special Dental Care of the Central Military Hospital in Utrecht, The Netherlands because of functional complaints of their mandibular denture. The group consisted of 1 female and 17 male subjects in the age ranging from 33 to 56 years, all healthy, fit for military service. The bone height in the inter-foraminal region exceeded 15 mm. All subjects gave informed consent. The Ethics Committee of the University Medical Centre Utrecht, The Netherlands, approved the study.

Surgical procedure

The subjects received 2 oral implants in the anterior part of the mandible (implant diameter 3.8 mm; implant length 13 or 15 mm) (Frialit-2, Friadent, Friedrichsfeld, Germany). The implants were placed in the region between the mental foramina, at the location of the former cuspids, according to a standardised surgical protocol. A vestibuloplasty according to Edlan-Mejchar was performed at the time of implant placement.

Second-stage surgery was performed 5 months after implant placement with two small crestal incisions at the location of the former cuspids. The implants were exposed, and the two healing collars replaced the two cover screws (Frialit-2, Friadent, Friedrichsfeld, Germany). A partial relining with a tissue conditioner (Soft-liner, GC Corporation, Tokyo, Japan) of the new mandibular denture base was now performed. This new denture base was made in the first weeks after first-stage surgery during the osseointegration of the implants.

Prosthetic procedure

Prosthetic procedures were started 1 week after first-stage surgery. A new, conventional upper and lower denture was made, according to a standard prosthetic scheme that included balanced articulation using anatomically shaped acrylic teeth (Bonartic, Ivoclar, Liechtenstein), maximal extension of the denture base and restoration of the vertical relation. In addition to anterior teeth, one bicuspid and two molars were used in the denture in each quadrant.

At the location of the submerged implants, ample space was left to allow for a partial relining with a tissue conditioner (Soft-liner, GC Corporation, Tokyo, Japan). The latter was done in order to not disturb the process of osseointegration of the implants. The patients wore these dentures for a period of approximately 3 months before returning for second-stage surgery (see Surgical procedure).

One week following second-stage surgery, the healing collars were removed and pick-up impression posts were placed at the implant level (Fig. 1). An impression was taken with a rigid impression material (Impregum, ESPE, Seefeld, Germany) using the 'new' mandibular denture as an open tray (Fig. 2). From this impression a master cast was poured. On this master cast, according to a randomisation protocol, the first of three types of attachments was fitted in the mandibular denture (Fig. 3).

The attachment type was changed after 3 and 6 months respectively. Because the same denture base was used, similar occlu-

Fig. 1. Pick-up impression-posts were placed at implant level and spaces around the posts were created in the mandibular denture for the impression material.

Fig. 2. Impregum impression material were poured around the impression-posts.

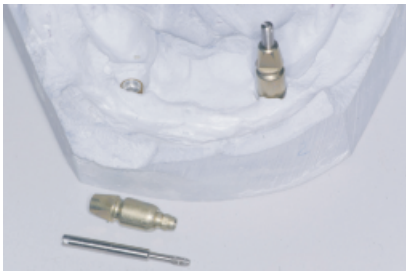

Fig. 3. From this impression a mastercast with two implant analogs was poured. On this mastercast the three attachment types were successively each after 3 months fitted in the mandibular denture.

sion and articulation, vertical height and denture base extension were maintained during the whole course of the trial.

The sequence in which the three attachments were applied was randomised. All 6 possible sequences were used, so that possible crossover effects could be studied. In that way, six groups of three subjects were formed, each having a different sequence of successive attachments. Each attachment type was used during a 3-month period.

The following types of attachment were used:

- Magnet attachment (Dyna magnet ES, type extra strong, Dyna Dental Engineering, Bergen op Zoom, The Netherlands). According to the manufacturer, the magnets provide a force of 4.4 N each. The magnet keepers were specially manufactured for this trial by Friadent (Friedrichsfeld, Germany) and are not commercially available. Magnets were incorporated in the denture base according to the manufacturer's instructions.
- Ball attachment (ball-socket attachment, Frialit-2, Friadent, Friedrichsfeld, Germany). The manufacturer does not document the retention force for these attachments.
- Bar-clip attachment (round bar in conjunction with a metal omega-shaped IMZ clip, Friadent, Friedrichsfeld, Germany). The manufacturer does not document the retention force for this attachment.

Two small perpendicular metal tubes were placed a few millimetres underneath the canines in the mandibular denture base (Fig. 4). In this manner the denture could be rigidly and reproducibly connected to the retention-measuring device.

Retention measuring device

A device was developed that allowed us to apply an increasing, vertical force on the denture (Rhybo, Utrecht, The Netherlands). The force was administered through a straight metal bar that was fitted with strain gauges (Measurements Group Inc., Raleigh, NC, USA). The bar was rigidly connected to the denture (Fig. 5). The patient was instructed to keep his chin firmly on a chin support (Fig. 6). Bending of the bar with increasing vertical forces was registered by the strain gauges and the applied force was expressed in Newton (Fig. 7). The force was increased gradually, until dislodgement of the denture occurred. The test was repeated five times.

Fig. 4. Two small perpendicular metal tubes placed a few millimetres underneath the canines in the mandibular denture base will receive the patrices of the measurment device.

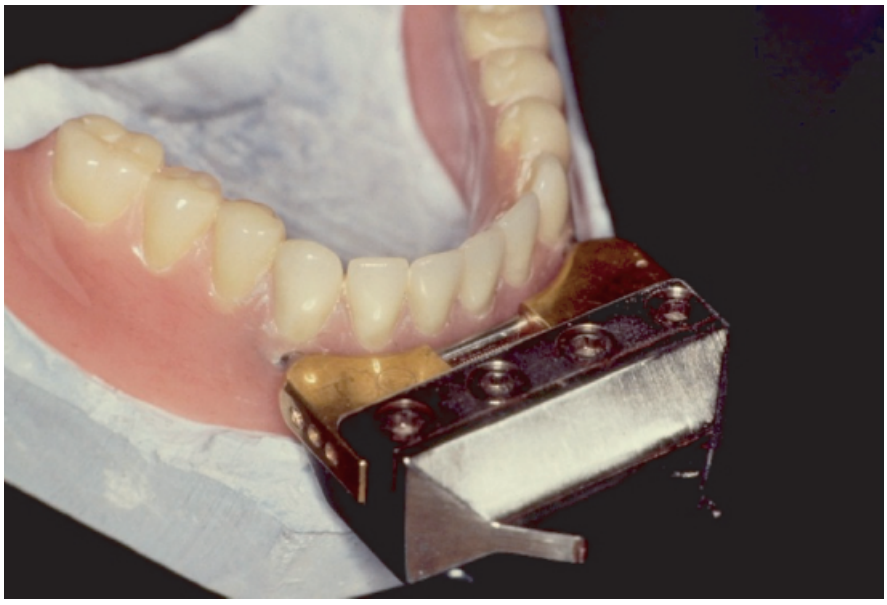

Fig. 5. The measurement device is rigidly connected to the denture.

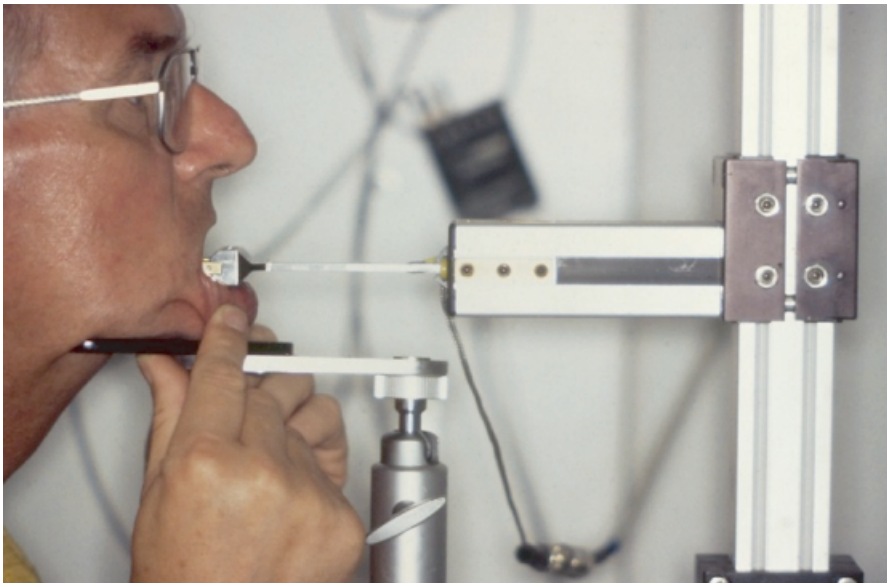

Fig. 6. The patient is instructed to keep his chin firmly on a chin support while an increasing vertical force is administered to the denture base.

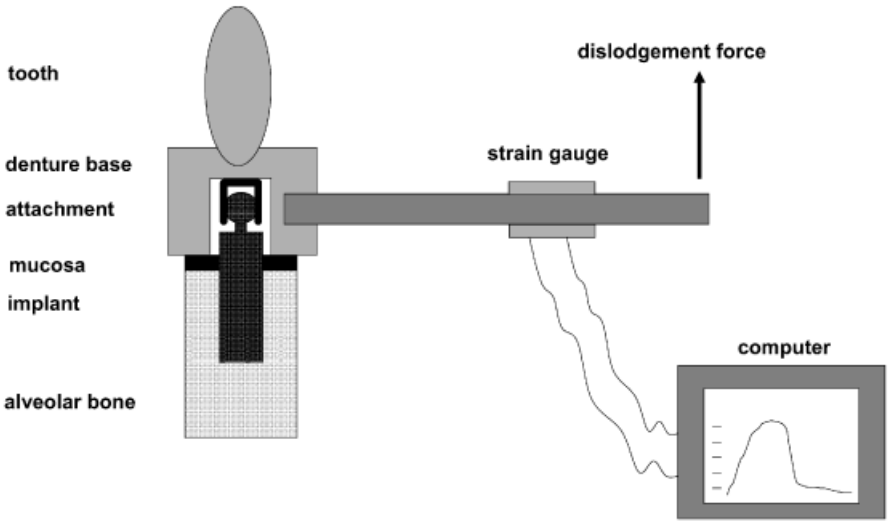

Fig. 7. Schematic representation of the experimental set up.

Moments of evaluation

In vivo measurements were performed one week after installation of the attachment in the denture (baseline) and after three months of function, for all attachment types respectively. Detailed records were kept with respect to post-insertion maintenance requirements during the course of the trial.

Statistical analysis

Analysis of variance (ANOVA) with repeated measures was applied to test possible differences in retention force, using the within-subject factors attachment type (magnet, ball, and bar-clip), moment of evaluation (baseline, and after 3 months of function), and repeats of measurement (five measurements).

Results

Retention force

The forces needed to dislodge the denture from the attachment are given in Table 1. Analysis of variance with repeated measures showed significant differences in retention force among the three attachment types ($P<0.001$). *Post hoc* analysis showed that the magnet attachment exhibited a significant lesser retention force in comparison with the ball and bar-clip attachments, whereas no differences were present between ball and bar-clip attachments. No significant differences in retention force were found among the five repeat measurements, and also not between the measurements at baseline and after 3 months of loading.

Prosthetic outcome

Functional maintenance complications related to the attachments were observed in magnet and ball attachments only, during the 3-month evaluation period. Signs of possible failure of magnet attachments occurred in 6/18 patients, involving 11 magnets. Nine magnets showed shiny spots whereas two magnets exhibited corrosion as a result of wear of the magnet keeper. Functional problems in the ball attachment group were seen in 4/18 patients. Two matrices loosened from the denture, and one ball attachment unsettled from the implant. Activating a matrix was deemed necessary in one patient. The bar-clip attachments showed no maintenance problems at all.

Discussion

In the literature, retention force is measured through objective means in both *in vitro* and *in vivo* (Burns et al. 1995a, 1995b; Petropoulos et al. 1997; Naert et al. 1999). *In vivo* measurements are preferable because intra-oral factors such as the presence of saliva is considered. With a retention force measurement device, the force needed to unlock the attachment when seated in the patient's mouth could be quite accurately assessed, with relative ease.

In the present *in vivo* study, the resistance against vertical dislodgement forces of the denture with magnet attachments is

***Table 1*. Force (in N) needed to dislodge the denture from the attachment as obtained for 18 subjects at baseline, and after 3 months of function (mean±SD)**

	Magnet	Bar-clip	Ball
Baseline	7.4±3.0	32.9±9.1	31.4±8.3
After 3 months	8.7±3.7	29.8±8.2	28.0±7.8

markedly less than those of the bar-clip and ball attachments. There is no significant loss of retention force after 3 months of loading for all three attachment types. It is interesting to note that baseline data for bar-clip, magnet and O-ring and dalbo-type attachments from various studies differ from our findings. Retention values in the present study are consistently higher (Table 2). This is presumably caused because of differences in the characteristics of the attachments used. Bearing in mind the differences in attachment systems that were employed in various studies, limited comparisons are possible. Burns et al. (1995a) compared the retention force of O-ring attachments and magnets after 6 months of function and, like us, found no loss of retention either. Possibly the loading period of 3 or 6 months is rather short for any retention loss to be noticeable. Other studies reported retention loss of magnet, ball (O-ring) and bar-clip attachments after a longer loading period, such as 5 years (Naert et al. 1999). This loss of retention was more pronounced in the bar-clip group. In the latter study the retention force of the ball attachment with rubber O-ring matrices is markedly lower than the bar-clip attachments.

The retention force of the ball and bar-clip attachments in our study do not differ significantly, because of the mechanical characteristics of the bar-clip and ball attachments. The O-ring ball attachment is quite different from the metal dalbo-type matrix, which was used in the present study. The metal matrix provides a larger retention force. The retention force for magnets is markedly less, when compared to bar-clip and ball attachments, irrespective of the brand of attachment used.

Postinsertion maintenance problems in a loading period of 3 months were observed with the magnet and ball attachments. By far, most problems occurred with the magnets. Eleven out of 36 magnet keepers had complications related to wear. Two magnets exhibited corrosion and nine showed shiny spots. Although the magnets were incorporated in the denture according to the recommendations of the manufacturer, that is, using a space maintainer, the magnet keeper and implant abutment must have had contact during oral function and thus created these complications. Probably the increasing bite forces of the subjects (van Kampen et al. 2002) and the insufficient thickness of the magnet keeper's space maintainer are responsible for this phenomen. In the longer run, more of these complications can be anticipated. These findings are in accordance with observations from other authors (Naert et al. 1999; Riley et al. 1999).

The ball attachments showed only a few minor, easy manageable complications. Four out of 36 attachments gave reason for treatment. Two matrices loosened out of the mandibular denture and had to be fastened by adding acrylic resin after 1 and 4 weeks of loading. One patrix part of the ball attachment unsettled after 2 days of loading and was refastened. One ball attachment matrix lost its retention capacity and had to be reactivated after a period of 2 weeks. All these complications occurred in subjects where the implants were not perfectly parallel to each other positioned in the mandible. The loading conditions of these attachments were therefore not as favourable as for more parallel inserted implants. In contrast to our findings, Davis & Packer (1999) did not see differences in the amount of postinsertion maintenance between ball (metal matrix) and magnet attachments. The large amount of maintenance for ball attachments as observed by Burns et al. (1995a) and Naert et al. (1999) must be contributed to the use of rubber O-ring attachments. Rubber O-rings are susceptible to stress and environmental forces such as friction, heat and commercially available denture cleaning agents. A lack of parallelism of the implants creates considerable wear of the rubber rings in a relatively short time span. They usually need replacement in 6–9 months (Winkler et al. 2002). In addition, Walton et al. (2002) also observed a considerable amount of post-insertion maintenance with the titanium Nobel Biocare ball attachments when compared to clip attachments used in that study.

The bar-clip attachments show no prosthetic complications at all during the 3-month observation period. In contrast to our findings, Gotfredsen & Holm (2000) noticed fewer maintenance problems with ball attachments on Astra implants (metal matrices) when compared to bar-clip attachments. Frequently observed problems by others with respect to the denture base (fracture or need for relining) were not encountered in this 3-month evaluation

***Table 2*. Comparison of vertical dislodgement forces for various attachments**

Authors	Measurement type	Bar-clip (N)	Ball (N)	Magnet (N)
The present study	In vivo	29.8 N*	28.0 N**	8.7 N‡
Naert et al. (1999)	In vivo	16.8 N‡‡	6.6 N§	3.7 N§§
Burns et al. (1995a)	In vivo	—	9.3 N¶	4.8 N¶¶
Petropoulos et al. (1997)	In vitro	21.1 N‖	24.4 N‖‖	1.3 N***

*Round dolder bar, omega-shaped metal IMZ clip (Friadent, Friedrichsfeld, Germany).
**Ball-socket attachment, metal matrix for Frialit-2 (Friadent, Friedrichsfeld, Germany).
‡Dyna magnet ES, type extra strong (Dyna Dental Engineering, Bergen op Zoom, The Netherlands).
‡‡Egg-shaped dolder bar with continuous clip (Cendres et Metaux, Biel, Switzerland).
§SDCB 115-17, O-ring attachment (Nobel Biocare, Gothenburg, Sweden).
§§Open field magnets, type undocumented (Dyna Dental Engineering, Bergen op Zoom, The Netherlands).
¶Integral O-ring (Calcitek Inc., not documented).
¶¶Shiner magnet (Preat Corp., San Mateo, USA).
‖Nobel Biocare bar and clip (Nobel Biocare, Gothenburg, Sweden).
‖‖Nobel Biocare ball attachment, presumably with a metal matrix, though not documented (Nobel Biocare, Gothenburg, Sweden).
***Zest Magnet (Zest Anchor Dental Attachment Systems, Escondido, USA).

period per attachment, nor during the 12-month observation period when all successive attachments are considered.

According to our patients the insertion of the denture in the mouth is easiest for the magnets and hardest for the ball attachments. One bar-clip connection is not hard to seat, whereas insertion of a denture with two ball attachments requires slightly more skills from the patient. After a few days the patients have all developed these skills and such problems have disappeared.

Conclusions

The retention force of magnet attachments in implant-retained mandibular overdenture treatment is markedly less than the retention force of ball and bar-clip attachments. The retention force does not change after 3 months, in function *in vivo*. Even after a short observation period of 3 months magnets are shown to be susceptible to wear. On the other hand, the amount of maintenance requirements for ball and bar-clip attachments in our study is limited. Other studies show a large variation in the necessary amount of postinsertion maintenance and retention with respect to ball attachments. We suggest that this is largely caused by a variation in characteristics of the ball attachment (matrix and patrix) that are employed.

In further studies the influence of these attachment types on oral function and clinical-prosthetic function needs to be investigated. Also treatment time, patient satisfaction, and initial costs and costs for repairs are parameters to look at more thoroughly.

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Résumé

Il serait logique de penser que les attaches qui procurent le plus de rétention contre les mouvements verticaux et horizontaux seraient également associées à des paramètres plus favorables des fonctions buccales. Cette étude *in vivo* a été menée pour apporter des données en rapport avec la force de rétention initiale, la perte de force de rétention après trois mois de mise en fonction, et le maintien et les complications après l'insertion associés avec l'utilisation d'aimants, de barres et de boules dans le traitement des prothèses amovibles inférieures. Dix-huit édentés ont reçu deux implants permuqueux dans la région interforamen de la mandibule, une nouvelle prothèse amovible et trois superstructures successives (attaches aimants, barres ou boules). La force de rétention des attaches lors de l'examen de départ et trois mois après a été mesurée d'une manière standard. La quantité et le type de maintien après l'insertion en relation avec le type d'attache ont été évalués. Aucune différence dans la force de rétention lors de l'examen initial et après trois mois de charge n'a été observée pour les trois types d'attache. Les forces de rétention moyenne pour les attaches avec aimants, barres et boules étaient respectivement de 8,1, 31,3 et 29,7 N. Les complications de maintien fonctionnel en relation avec les attaches étaient essentiellement observées dans onze des trente six attaches aimants. Les problèmes fonctionnels dans le groupe attache par boules étaient relativement rares, faciles à gérer et aperçus au niveau de 4/36 attaches. Les attaches barres ne s'accompagnaient d'aucun problème de maintien.

Zusammenfassung

Retention und Unterhaltsbedarf von Steg-, Kugel- und Magnetverankerungen bei implantatgetragenen Hybridprothesen im Unterkiefer; ein in vivo Vergleich über eine Tragdauer von 3 Monaten

Es kann die Hypothese aufgestellt werden, dass Retentionselemente, welche mehr Stabilität gegen vertikale und horizontale Verlagerung bieten, mit besseren Parametern bezüglich oraler Funktion assoziiert sind. Diese *in vivo* Studie wurde entwickelt, um Daten bezüglich initialer Retentionskraft, Verlust an Retentionskraft nach 3 Monaten in Funktion, Unterhaltsbedarf und Komplikationen in Zusammenhang mit der Verwendung von Magnet-, Steg- und Kugelverankerungen bei Hybridprothesen im Unterkiefer zu liefern.

Achtzehn zahnlose Subjekte erhielten zwei transmukosale Implantate in der interforaminalen Region des Unterkiefers, eine neue Prothese und drei erfolgreiche Verankerungselemente (Magnet-, Steg- und Kugelverankerung). Die Retentionskraft der Retentionselemente wurde bei der Ausgangsuntersuchung und nach 3 Monaten mit einer standardisierten Methode gemessen. Die Anzahl und Art der Unterhaltsarbeiten in Relation zu den verschiedenen Retentionselementen wurde evaluiert.

Es bestanden keine Unterschiede in der Retentionskraft zwischen der Ausgangsuntersuchung und 3 Monate nach Belastung für alle 3 Befestigungsarten. Die mittlere Retentionskraft betrug für die Magnetbefestigung 8.1N, für die Stegverankerung 31.3N und für die Kugelverankerung 29.7N.

Funktionelle Komplikationen in Zusammenhang mit den Befestigungselementen wurden vornehmlich bei 11 von 36 Magnetverankerungen beobachtet. Funktionelle Probleme bei den Kugelankern waren relativ selten zu beobachten, nämlich bei 4 von 36 Ankern, und leicht zu beheben. Die Stegverankerungen zeigten keine Probleme im Unterhalt.

Resumen

Se podría hipotizar que los ataches, que suministran más retención frente al desplazamiento vertical y horizontal, se asociarían con unos parámetros más favorables de función oral. Este estudio *in vivo* está diseñado para proporcionar datos acerca de la fuerza de retención inicial, pérdida de fuerza de retención tras 3 meses de función y mantenimiento post-inserción y complicaciones asociadas con el uso de imanes, clip de barra y ataches de bola en el tratamiento de las sobredentaduras mandibulares.

Dieciocho sujetos edéntulos recibieron dos implantes permucosos en la región interforaminal de la mandíbula, una nueva dentadura y tres modalidades sucesivas de supraestructura (imanes, clip de barra y ataches de bola). Se midió de una manera estandarizada la fuerza de retención de los ataches al inicio y tras 3 meses. Se evaluaron la cantidad y el tipo de mantenimiento post-inserción en relación con los ataches.

No se observaron diferencias en la fuerza de retención al inicio y tras 3 meses de carga para los 3 tipos de ataches. Las fuerzas de retención medias de los ataches magnéticos, los ataches de clip de barra, y los ataches de bolas fueron de 8.1, 31.3 y 29.7 N respectivamente.

Las complicaciones funcionales de mantenimiento relacionadas con los ataches fueron predominantemente observadas en 11/36 ataches magnéticos. Los problemas funcionales fueron relativamente raros, fácilmente manejables y observados en 4/36 ataches. Los ataches de clip de barra no exhibieron ningún problema de mantenimiento.

要旨

垂直及び水平方向の脱落力に対して強い維持力を発揮するアタッチメントは、口腔機能の好ましいパラメータに寄与しているという仮説を立てうる。本ｉｎ ｖｉｖｏ研究は、下顎オーバーデンチャーにおけるマグネット、バークリップ及びボール･アタッチメントの使用に関する、初期維持力、機能開始３ヵ月後の維持力の喪失、挿入後のメンテナンス及び合併症についてのデータを集めた。

１８名の無歯顎患者において、下顎オトガイ孔間に２本の粘膜貫通型インプラントを植立し、新しい義歯と３種類の上部構造様式（マグネット、バークリップ、ボール・アッタチメント）を付与した。ベースライン時と３ヶ月後のアタッチメントの維持力を通法によって測定した。アタッチメントに関する挿入後のメンテナンスの量と種類を評価した。

ベースラインと荷重３ヵ月後の維持力には、３種類のアタッチメントにおいて、いずれも差異は観察されなかった。磁性アタッチメント、バークリップ、ボール・アタッチメントの平均維持力は各々８．１Ｎ、３１．３Ｎ、２９．７Ｎであった。

アタッチメントに関する機能的メンテナンスの合併症は、主として３６個の磁性アタッチメントのうち１１個で観察された。ボール・アタッチメント群では機能的問題は比較的まれであり、対処しやすく、３６個中４個のアタッチメントで認められた。バークリップ・アタッチメントはメンテナンスの問題は全く無かった。

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