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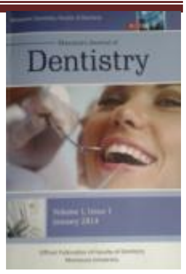

Effect of different attachments designs used for implant assisted mandibular distal extension RPD. An in vitro study of stresses transmitted to abutment teeth

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Abstract:
Objectives: This in vitro study compared between different designs of solitary attachments used to retain implant assisted mandibular distal extension RPD regarding stresses on abutment teeth.
Methods: A mandibular Kennedy Class I was selected with remaining natural teeth from the first premolar on one side to first premolar on the other side. A heat cure acrylic risen model was duplicated and three removable partial denture were fabricated from a cobalt chromium metal framework and acrylic occlusal rims. Strain gauges were placed on the acrylic model at mesial, lingual and distal surfaces to measure the strain around abutment teeth. Two Dentaurum® implants were then placed in the first molar regions and the removable partial dentures were connected to implants using three different attachment namelly ball, magnetic and locator attachments. The model was loaded by 60N unilaterally and bilaterally on first molar areas.
Results: Comparison of combined strain around abutment teeth (average strain of buccal, lingual and distal strain gauge positions) between groups during bilateral and unilateral (loading and non-loading sides) load application was made. There was a significant difference between groups during bilateral and unilateral loading (Kruskal Wallis test, p=.00). Magnetic assisted RPOD demonstrated the highest strain, followed by locator assisted RPOD and the lowest strain was recorded with ball assisted RPOD. The highest strain was recorded at the lingual surface and the lowest strain was recorded at the distal surface of abutment teeth.
Conclusion: In spite of using implant attachments for assisted distal extension RPOD, the abutment teeth still subjected to a considerable stress under loading. During load application, ball attachment used to retain implant assisted DERPOD recorded the lowest strain around abutment teeth compared to locator and magnetic attachment.

***Keywords*:** *Implant, removable partial denture, implant assisted, implant attachment, stresses.*

Introduction

Although implant-supported fixed partial dentures are the ideal treatment option for partially edentulous patients, bone loss in mandibular posterior regions could require bone graft and mandibular nerve lateralization procedures for implant placements, presenting high surgical risk and cost and discouraging patients [1,2]. Thus, removable partial dentures (RPDs) still represent an alternative of rehabilitation for these patients. Distal extension RPDs are complex because of the teeth and mucous support, requiring better load distribution for both tissues to avoid vertical, horizontal and torsional forces that may have adverse effects [3,4]. The use of distal implants to support and retain RPDs has been reported in the literature to minimize dislodgement, improve esthetics and mastication and increase patient satisfaction in cost-effective manner [3-5]. The commonly used abutment types for connections between the denture and interforaminal implants are bars, ball attachments, magnets and telescopic crowns, which offer different biomechanical features [6,7]. Appropriate choice of attachment can be made on the basis of the given anatomical state of the mandible. Advanced atrophy of the alveolar crest calls for prosthesis stabilization especially with regard to horizontal forces; this is best achieved using bars or parallel-walled telescopic crowns [8]. In mandibles that provide sufficient bone quantity, magnet connectors constitute an alternative solution, although their easy handling is often in conflict with patients' desire for better retention [9]. A pointed (v-shaped) jaw, which leaves insufficient tongue space for a bar construction, indicates that single attachments are to be used [10].

The ball attachment are less costly, less technique sensitive [11], easier to clean [12]. In addition, less wear or fracture of the component than bars [13]. Moreover, the potential for mucosal hyperplasia reportedly is more easily reduced with ball attachments [14]. It was also reported that the use of the ball attachment might be advantageous for implant-supported over-dentures with regard to optimizing stress and minimizing denture movement [15]. Magnetic attachments have been applied as retention systems since the 1950s and are widely used in both natural teeth and dental implants [16,17]. One of the greatest advantages of magnetic attachments is their reduced lateral forces, since lateral forces can badly influence the supporting teeth or implants. However, some clinical studies have shown that the retentive forces of magnetic attachments are significantly lower than those of bar or ball attachments (18,19). In addition, the designs of magnetic attachments have been associated with a number of problems including [18,19] corrosion, wear, and demagnetization [20]. The Locator attachment (Zest Anchors, Inc, homepage, Escondido, CA, USA) which was introduced in 2001 is a new system, which does not use the splinting of implants. This attachment is self-aligning and has dual retention and in different colors with different retention values [21-23]. Locator attachments are available in different vertical heights, they are resilient, retentive, and durable, and have some built-in angulation compensation. In addition, repair and replacement are fast and easy [24-26].

Several investigation evaluated stresses around implant and abutment teeth with supporting IADERPOD. However, the effect of different types of attachments on stresses around abutment teeth with IADERPOD was not a concern. Therefore, this in vitro study aimed to compare between different designs of solitary attachments used to retain implant assisted mandibular distal extension RPD regarding stresses on abutment teeth. The null hypothesis was that there will be no significant difference between different solitary attachments used to IADERPOD.

Materials and methods

This in-vitro study was carried out on mandibular Kennedy class I heat cure acrylic model (simulation model) which was constructed by a duplication of commercially available partially edentulous stone model (with remaining teeth from first premolar to first premolar and well-formed bilateral residual ridges) [27]. The root forms were coated with 0.3 mm thick elastomeric membrane to simulate the periodontal ligament. Another layer of elastomeric membrane, uniform thickness of 2 mm of the same material (Promedica, GmbH, Neumünster، Germany), was used to fabricate a soft tissue replica at the distal extension region. Two implants (3.7mm in diameter, 13mm in length; TioLogic, Dentaurum, Germany) were placed bilaterally in the canine region vertical to the residual ridge. The implants were retained using resin cement (SuperBond CB; Sun Medical, Japan) (Fig. 1). The removable partial denture was fabricate to accommodate three different attachment ball, magnetic and locator attachments (Fig. 2). Three conventional cobalt-chrome bilateral distal extension RPDs with a lingual bar and RPA (mesial occlusal rests, distal proximal plate, and Aker retentive arm) on both first premolars where designed. A wax occlusion rim was constructed on one metallic framework without any denture teeth [28-30] and the occlusal plane was oriented to the level of the retromolar pad. The wax rim was then duplicated on the other frameworks.The metal frameworks with attached occlusion rims were flasked. After wax elimination, heat-cured denture base resin (Lucitone 199, Dentsply, USA) was packed and polymerized according to the manufacturer's instructions to obtain acrylic occlusion rim.

All strain gauges had a gauge factor of 2.08±1.0%. Therefore, by placing the value of the output voltage in the strain equation, the value of strain could be calculated. The gauges type was KFG-1-120-C1-11L1M2R (Kyowa electronic instrument co.,LTD Tokyo, Japan), with the temperature coefficient of resistance of +.008% per degrees Celsius.The nominal resistance for the gauges was 140.4±0.4Ω, and the gauges dimensions were 1.0mm. Six strain gauges were placed directly on the surface of the acrylic resin [6], to place the measuring grid of the gauges closer to the abutment teeth at distal, mesial and lingual surfaces for both sides. The terminals of the six strain gauges wires were connected to a digital multichannel strain meter (Tinsley and Co. Ltd., Werndee Hall, London, H. Model 8692) that connected to a compatible computer containing the meter control software (Kywa PCD 300A). The strain meter was run in a quarter-bridge circuit, which electrically amplified the small signals of resistance change of the strain gauge and then convert the microvoltage output into microstrain by the software to provide direct reading. Before strain-gauge measurements, a cyclic loading ranging from 10 to 60N was applied 5 times to different locations of each prosthesis to "age" the strain gauges and minimize hysteresis, a lagging or retardation of the effect when forces acting on a body are changed [31,32]. This load was applied at a crosshead speed of 0.5mm\min using a universal testing machine (LLOYD LRX, LLOYD instruments Ltd., Fareham, and Hampshire, UK). A bar that used for the bilateral vertical loading condition at first molar area [28-30,33], a unilateral vertical load application at central occlusal fossa of the right first molar and notched in the acrylic resin surface of record block with a diamond bur to prevent slippage of the pin [34].

All measurements were repeated 5 times for each experimental denture, allowing at least 5 minutes for recovery and the mean recorded micro strain was subjected to statistical analysis [35], for each group was calculated and compared within each loading protocol by the Kruskal-Wallis test followed by post hoc tests with confidence levels set at 95%.

Results

Comparison of combined strain around abutment teeth (average strain of buccal, lingual and distal strain gauge positions) between groups (ball assisted RPOD, magnetic assisted RPOD and locator assisted RPOD) during bilateral and unilateral (loading and non-loading sides) load application. There was a significant difference between groups (Kruskal Wallis test, p=.00). Magnetic assisted RPOD demonstrated the highest strain, followed by locator assisted RPOD and the lowest strain was recorded with ball assisted RPOD. Multiple comparisons between each two groups (post hoc test) are presented in table 1 and table 2.

At distal strain gauge positions, There was no significant difference between groups in bilateral loading application (Kruskal Wallis test, p= .581). At distal site of loading side, There was no significant difference between groups (Kruskal Wallis test, p= .074) is presented in table 2. At distal site of non-loading side, There was no significant difference between groups (Kruskal Wallis test, p= .058) is presented in table 2.

During bilateral load application, for ball and magnetic assisted RPOD, There was a significant difference between strain gauges positions (Kruskal Wallis test, p= .00). Lingual position demonstrated the highest strain, followed by buccal position and the lowest strain was recorded with distal position. Multiple comparison between each two strain gauges positions (post hoc test). However a locator assisted RPOD, There was a significant difference between strain gauges positions (Kruskal Wallis test, p= .00). Buccal and lingual positions demonstrated the highest strain, without significant differences in between and the lowest strain was recorded with distal position. Multiple comparisons between each two strain gauges positions (post hoc test) were shown in table 3.

During unilateral load application a ball attachment, There was a significant difference between strain gauge positions (Kruskal Wallis test, p= .001). The highest strain was recoded at lingual non-loading side (LNL) and the lowest strain was recorded at buccal loading side (BL). Multiple comparison between each two groups (post hoc test). However, in magnetic and locator attachments was a significant difference between strain gauge positions (Kruskal Wallis test, p= .00). The highest strain was recorded at buccal loading side (BL) and the lowest strain was recorded at distal non-loading side (DNL). Multiple comparisons between each two groups (post hoc test) were shown in table 4.

Discussion

According to the results of this study, when comparing the combined strains around abutment during bilateral loading sides a statistically significant different was found between all groups and between each two groups, magnetic assisted RPOD recorded the highest strain around abutment and the ball assisted RPOD recorded the lowest strain around abutment teeth.

The fact that magnets have a direct contact with their keepers without intervening space, may be responsible for transmission of the axial force to the implants [36] with extremely low lateral stress potential because they slide over the keeper unit with little loss of vertical retention **[**37**]**. The vertical forces transmitted to the abutment via mesial rest are well tolerated due to buttressing effect of the adjacent teeth [38], while lateral forces are transmitted to the abutment at buccal and lingual surface. These forces are difficult to be controlled by magnetic attachments.

Locator attachments showed a reduced strain around abutments compared to magnetic attachments. This could be attributed to the structural property of the locator attachment and the matrix-patrix relationship that may affect stress transfer to the abutments and the implants. Locator has a dual retention comes from the presence of internal and external flanges present in the male nylon inserts [39]**.** Theses frictional flanges provide limited lateral movements to the prosthesis [40]. Thus, more stresses are transferred to the implants and low stresses are transferred to the abutments.

On the other hand, locator attachments showed a more strain around abutments compared to ball attachments. This may be due to locators have vertical resiliency which provide stress relief on the implants. The Locator® attachment allows movements of the prosthesis in both the vertical plane and the hinge axis. The resiliency is achieved with the design of the black processing patrix. When the processing patrix is replaced by the definitive nylon patrix, a space of 0.2 mm is created to allow for vertical resiliency and 8◦ hinging in any direction [25,41]**.** This vertical resiliency provides a limited vertical movement of the distal extension part of the prosthesis that may transmit forces to the abutments. The ball attachment recorded the lowest strain around abutments in comparison to other attachments. This could be attributed to several factors that increase stress concentration on the implants and decrease stresses around the abutments. Firstly, ball attachments used in this study are supplied in form of ball and sockets, which consists of titanium ball and platinized gold sockets. The ball and socket contact each other without intervening space. Therefore, it does not permit vertical movement of the prostheses due to absence of vertical resiliency. Secondly, ball and socket attachments provide positive posterior vertical stopper that limit the movement of the distal extension part of the prosthesis. Thirdly, ball and socket attachments also limit the lateral movement of the prosthesis in comparison to magnetic attachments due to the flanges of the platinized gold sockets contact the ball head during lateral movements. In another study, it was shown that the ball attachment might provide increased stability than magnetic attachment [42]**.** Finally, the occlusogingival height of the ball anchors was larger than the height of locator and magnetic attachment. This height may transfer more stresses to the implants rather during posterior occlusal load [43]**.** Therefore, in a study of the ratio of the length of implant in the alveolar bone to the length of implant exposed outside the bone, the authors suggested that the ball attachment should be as short as possible to decrease stress by minimizing the lever arm effect [44]. All these factors make the implants bear most of the applied load and provide stress relief to the abutments.

At distal strain gauge position, during bilateral and unilateral (at loading and non-loading sides) load application; there was no significant difference in strain recorded around abutments between the three tested attachments. This could be attributed to the effect of mesially placed occlusal rest which directs tipping forces toward the mesial surfaces which will bring the abutment in firm contact the adjacent teeth providing a buttressing effect [38] regardless of the attachment system used.

During bilateral loading, the highest strain was recorded for the lingual position for ball and magnetic attachments. The greater micro-strains recorded from the lingual strain gauge may be explained by the slight lingual anatomic inclination of the mandibular abutment teeth [45,46]**.** During unilateral load application, comparison between strain gauge positions yields variable results according to the type of attachment. For ball attachment, the highest strain was recorded at lingual position of non-loading side. While load was applied on the loading side, the denture may displaced inward on the non-loading side causing a stress concentration at lingual position of non-loading side around abutments due to the upper edges of the cortical bone plate which had the potential tendency to be displaced inward in the horizontal plane as mentioned previously. Shahmiri, et al.[47] Observed that unilateral loading created lateral and vertical displacement of the IARPD and an off-axis lever is created on non-loading side, resulting in a twisting of the metal structure. For magnetic attachments, the highest strain was recorded at buccal position of loading side. This may be due to magnets offer little resistance to lateral forces at loading side which may cause shift of the denture in buccal direction and stress concentration buccal position of the abutment at loading side.

Overall, the null hypothesis was rejected, as ball attachments was associated with the least stresses around abutments when used to retain IADEPOD compared to magnetic and locator attachments.

Conclusion

Within the limitation of this in vitro strain gauge analysis, the following conclusions could be drawn:

1.In spite of using implant versus attachments for assisted distal extension RPOD, the abutment teeth still subjected to a considerable stress under loading.

2.During load application, ball attachment used to retain implant assisted DERPOD recorded the lowest strain around abutment teeth compared to locator and magnetic attachment.

3. The highest strain was recorded at the lingual surface and the lowest strain was recorded at the distal surface of abutment teeth.

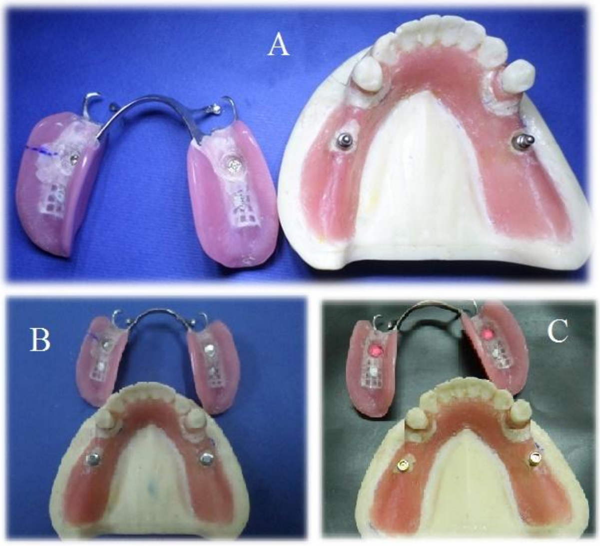

Figure 1: Attachment assisted partial overdenture, A- ball attachment B- Magnetic attachment and C- locator attachment.

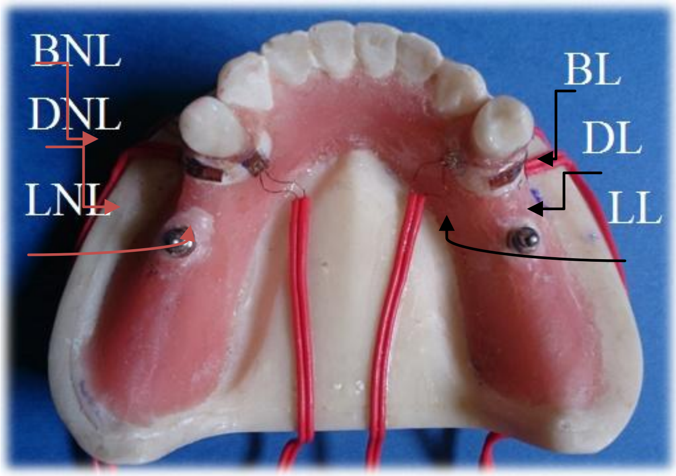

Figure 2: Strain gauges positions around premolar abutments in loading and non-loading side. BL; Buccal on loading side), LL; Lingual on loading side, DL; Distal on loading side, LNL; Lingual on non-loading side, BNL; Buccal on non-loading side, DNL; Distal on non-loading side.

Table 1:. Comparison of strain around abutments between groups during bilateral load application.

	Buccal (B)	Lingual (L)	Distal (D)	Total strain
Ball assisted RPOD M (min-max)	60.0000 (50.0-70.0)	187.5000 (75.0-300.0)	30.0000 (10.0-45.0)	60.0000 (10.0-300.0)
Magnetic assisted RPOD M(min-max)	210.0000 (195.0-310.0)	497.5000 (55.0-990.0)	7.5000 (-15.0-30.0)	130.0000 (-15.0-990.0)
Locator assisted RPOD M(min-max)	-222.5000 (-340--125.0)	-152.5000 (-200--105.0)	-20.0000 (-30.0--20.0)	-117.5000 (-340.0--20.0)
Kruskal Wallis test (p value)	.00*	.019*	.581	.00*

M=median, min=minimum, max=maximum, *= p value is significant at 5% level of significance.

Table 2: Comparison of strain around abutments between groups during unilateral load application.

	Buccal on loading side (BL)	Lingual on loading side (LL)	Distal on loading side (DL)	Lingual on non-loading side (LNL)	Buccal on non-loading side (BNL)	Distal on non-loading side (DNL)
Ball assisted RPOD M	-11.0000	-18.0000	-23.0000	-33.0000	-18.0000	-14.0000
Min	-15.00	-20.00	-30.00	-45.00	-20.00	-15.00
Max	-10.00	-15.00	-15.00	-20.00	-15.00	-10.00
Magnetic assisted RPOD M	-1402.00	1081.000	42.0000	-433.000	202.0000	-21.0000
Min	-1435.00	1070.00	35.00	-435.00	200.00	-25.00
Max	-1375.00	1095.00	50.00	-430.00	205.00	-20.00
Locator assisted RPOD M	-287.000	-225.000	-51.0000	-65.0000	-71.0000	-64.0000
Min	-330.00	-245.00	-55.00	-70.00	-75.00	-70.00
Max	-250.00	-200.00	-50.00	-60.00	-65.00	-60.00
Kruskal Wallis test (p value)	.006*	.002*	.074	.003*	.006*	.058

M= median, min=minimum, max=maximum, *= p value is significant at 5% level of significance.

Table 3: Comparison of strain around abutments between strain gauges positions during bilateral load application.

	Ball assisted RPOD	Magnetic assisted RPOD	Locator assisted RPOD	Total strain
Buccal (B)				
M	60.5000	223.5000	-227.5000	170.5000
Min	50.00	195.00	-340.00	50.00
Max	70.00	310.00	-125.00	340.00
Lingual (L)				
M	188.5000	509.5000	-152.0000	283.3333
Min	75.00	55.00	-200.00	55.00
Max	300.00	990.00	-105.00	990.00
Distal (D)				
M	30.0000	8.0000	-22.0000	24.3333
Min	10.00	-15.00	-30.00	10.00
Max	45.00	30.00	-20.00	45.00
Kruskal Wallis test (p value)	.00*	.00*	.00*	.025*

M=median, min=minimum, max=maximum, *= p value is significant at 5% level of significance.

Table 4: Multiple comparison between each two strain gauge positions (post hoc test) for each group during unilateral load application.

	Ball assisted RPOD	Magnetic assisted RPOD	Locator assisted RPOD
BL-LL	.035*	.00*	.366
BL-DL	.002*	.007*	.00*
BL-LNL	.00*	.368	.003*
BL-BNL	.035*	.00*	.041*
BL-DNL	.404	.049*	.002*
LL-DL	.308	.048*	.00*
LL-LNL	.049*	.00*	.039*
LL-BNL	1.00	.368	.255
LL-DNL	.201	.007*	.026*
DL-LNL	.364	.049*	.120
DL-BNL	.308	.368	.013*
DL-DNL	.022*	.368	.164
LNL-BNL	.049*	.007*	.356
LNL-DNL	.001*	.368	.871
BNL-DNL	.201	.072	.278

* p value of Mann Whitney test is significant.

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