Effect of Attachment Type, Maximum Occlusal Force, and Denture Deformation on Marginal Bone Loss of Two-Implant Overdentures: A Short-Term Clinical Trial

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Purpose: This study aimed to investigate the effect of attachment type, maximum occlusal force, denture deformation, and other confounding factors on marginal bone loss of two-implant overdentures after 1 year. ***Materials and Methods:*** Ninety edentulous patients received two implants in canine areas of the mandible using the computer-guided flapless surgical technique. Three months later, overdentures were connected to the implants with bar, resilient telescopic, and resilient stud attachments. Marginal bone loss was evaluated using standardized digitized periapical radiographs. Maximum occlusal forces were evaluated using a digital bite-force meter. Denture base deformation (denture strains, μm) was evaluated using strain gauges bonded to the polished surface of the denture at the level of the attachments. Regression analysis was adopted to find the relation between marginal bone loss and the following confounders (age, sex, mandibular bone height, period of edentulism, number of previous dentures, attachment type, maximum occlusal force, and denture strains). ***Results and Conclusion:*** Telescopic overdentures showed the highest marginal bone loss and maximum occlusal force, followed by bar overdentures, and stud overdentures demonstrated the lowest values. The highest denture strains were noted with bar overdentures, followed by telescopic overdentures, and stud overdentures showed the lowest strains. Age (P = .022), mandibular bone height (P = .023), number of previous dentures (P = .004), maximum occlusal force ($P \leq .001$), and denture strains (P = .048) were significantly correlated with marginal bone loss. For every 1-year increase in age, there was a decrease in bone loss by 0.3%. For every 1-mm increase in bone height, there was an increase in bone loss by 1%. For every one increase in the number of worn dentures, there was a decrease in bone loss by 4.2%. For every 10-N increase in maximum occlusal force, there was an increase in bone loss by 6.4%. For every 10-μm increase in denture strains, there was an increase in bone loss by 0.21%. Sex, time of edentulism, and attachment type did not demonstrate a significant correlation with marginal bone loss. *Int J Oral Maxillofac Implants 2022;37:391–399. doi: 10.11607/jomi.8982*

Keywords: attachment, denture deformation, implant, marginal bone loss, maximum occlusal force, overdentures

The use of mandibular overdentures supported by two implants has become a routine procedure in the rehabilitation of edentulous patients, as it improves denture stability and retention. Moreover, two-implant overdentures can enhance chewing efficiency, patient satisfaction, and electrical activity of masticatory muscles.[1] Different retention systems may be used to connect the overdentures to the implants, such as splinted (bar) or unsplinted (spherical, magnetic, telescopic, and resilient stud-type) attachments.[2] The selection of specific attachment should consider ridge resorption, arch shape, available restorative space, desired retention and stability of the prosthesis, ease of fabrication and maintenance, implant parallelism, and costs.[3] Moreover, the type of attachments that provide good load distribution to the implants should be considered.[4] Bar (splinting) connectors share and distribute the load to the implants[5,6] and have a reduced rate of prosthetic maintenance.[7] However, bars have a higher incidence of mucosal hyperplasia.[7] Telescopic (double) crowns are self-aligned and can be used in patients with advanced ridge resorption to improve prosthesis stabilization.[8] The resilient stud (locator) anchors have double retention values from internal and external frictional flanges of the plastic inserts.[3] Moreover, it is indicated with reduced interarch distance and can compensate implant angulation.[9,10]

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Submitted September 11, 2020; accepted January 10, 2021.

Table 1 Baseline Characteristics of All Groups

	Bar overdentures	Telescopic overdentures	Stud overdentures	*P* value
Age (y)	59.38 ± 6.89	60.38 ± 6.32	58.63 ± 6.82	.872
Sex (male/female)	14/16	15/15	17/13	.58
Height of mandibular bone (mm)	26.38 ± 2.00	26.25 ± 1.83	26.63 ± 2.39	.935
Time of edentulism (y)	5.13 ± 1.13	5.38 ± 0.92	4.63 ± 0.74	.290
No. of previous dentures	1.75 ± 0.71	2.00 ± 0.93	1.50 ± 0.76	.472

Marginal bone loss is a crucial issue that affects implant success and clinical outcomes after rehabilitation with dental implants.[11] The normal range of marginal bone loss is < 1 mm in the first year and < 0.2 mm annually.[12] Marginal bone loss of > 0.44 mm after 6 months of prosthesis delivery may be considered an indicator of progressive marginal bone loss that may occur later.[13] Multifactorial causes for bone loss are not fully understood.[11] There are two main theories that include infection (peri-implantitis) and overload.[14] However, there is clear evidence that a single-minded explanatory model for bone loss is not acceptable.[11]

In recent systematic reviews,[15,16] the attachment type was found to have no effect on bone loss of implants retaining mandibular overdentures. However, the investigated attachments did not include resilient studs (locators) and resilient telescopic attachments. There is a need for studies evaluating marginal bone loss with other types of attachments.[17] Several studies found that implant-assisted overdentures improve the maximum occlusal force of edentulous individuals.[18–20] The effect of maximum occlusal force on marginal bone loss is a matter of controversy. Geckili et al[21] found that the bone loss of implants assisting mandibular overdentures was influenced by maximum occlusal force. However, van Kampen et al[22] could not demonstrate a relationship between maximum occlusal force and marginal bone loss. The attachment types have different sizes and occupy different spaces in the denture base. Therefore, they are associated with different degrees of denture deformation.[23,24] The denture deformation could transfer more load to the supporting implants, especially at the area of abutment teeth.[23,24] This load, if it exceeds the physiologic limit, may lead to marginal bone loss. The present study aimed to evaluate the effect of attachment type, maximum occlusal force, denture deformation, and other confounding factors on bone loss of two-implant overdentures after 12 months of denture use. The null hypothesis was that marginal bone loss will not be affected by the tested confounding factors.

MATERIALS AND METHODS

Ninety edentulous patients who participated in a previous trial[25] were selected for this study. The participants were required to have *(1)* retention problems in the mandibular dentures, *(2)* sufficient bone volume in canine regions (class IV–VI Cawood and Howell),[26] *(3)* adequate bone density (classes I–III Lekholm and Zarb),[27] and *(4)* at least 15 mm of restorative space (class I according to Ahuja and Cagna).[28] Patients with the following conditions were excluded: *(1)* uncontrolled diabetes, hyper parathyrodism, and osteoporosis; *(2)* radiation therapy in the head region; and *(3)* smoking. Power analysis was performed based on the results of a previous study[29] in which the authors found a significant difference in marginal bone loss between overdenture attachments (effect size = 0.40 mm, standard deviation [SD] = 0.20 mm, α = .05, β = .90). The analysis was made to yield 30 patients per group, anticipating 15% dropouts. Patients were stratified into blocks regarding the following covariates: age, sex, number of previous dentures, bone height in the interforaminal region, and time of edentulism (baseline characteritics, Table 1). The participants were then allocated into groups using the balanced (stratified) randomization procedure.[30] Simple randomization (using random numbers generated in an Excel sheet) was performed within each block to assign subjects to one of the groups. This procedure aimed to control and balance the influence of covariates to ensure that there was no difference between groups regarding the baseline criteria. The groups included *(1)* bar overdentures (n = 30), where patients received mandibular two-implant overdentures with Dolder bar attachments (Fig 1); *(2)* telescopic overdentures (n = 30), where patients received mandibular two-implant overdentures with resilient telescopic attachments (Fig 2); and *(3)* stud overdentures (n = 30), where patients received mandibular two-implant overdentures with resilient stud (locator) attachments (Fig 3). Consents were obtained from all patients, and the protocol was approved by the Ethical Committee of the Faculty (no. 10111218). The study was conducted according to CONSORT guidelines.

For each patient, a preoperative CBCT was used to construct a mucosal-supported stereolithographic guide. Two implants (tioLogic, Dentaurum) were placed in canine regions using the computer-guided flapless surgical technique. After 3 months, the open-tray impression procedure was performed.[31] For bar overdentures,

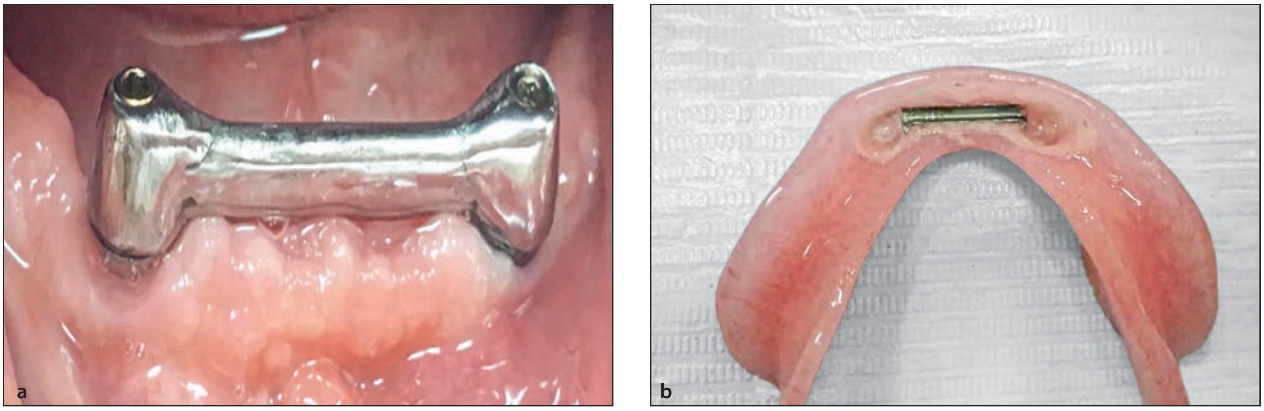

Fig 1 Bar overdentures. *(a)* The bar screwed to the implants. *(b)* Titanium clip attached to the denture.

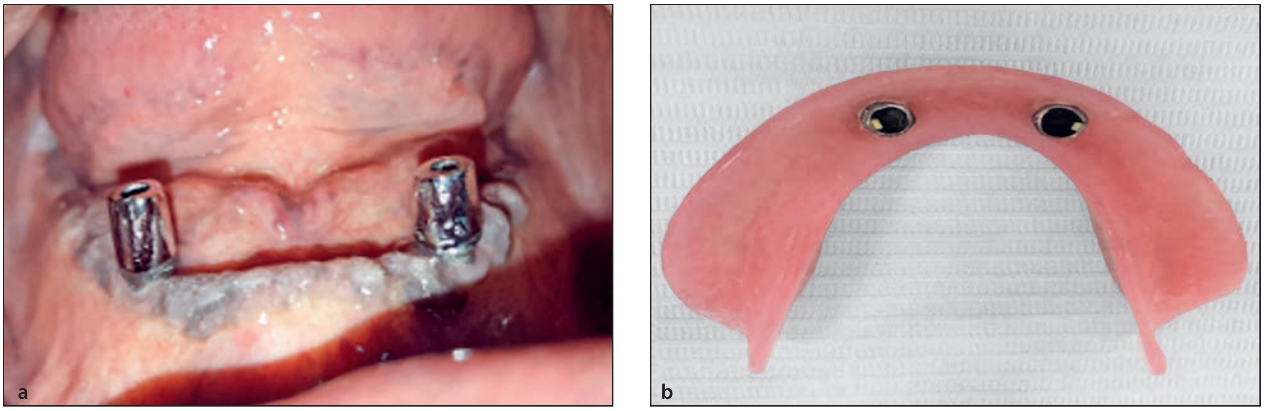

Fig 2 Telescopic overdentures. *(a)* The primary crowns screwed to the implants. *(b)* The secondary crowns attached to the denture.

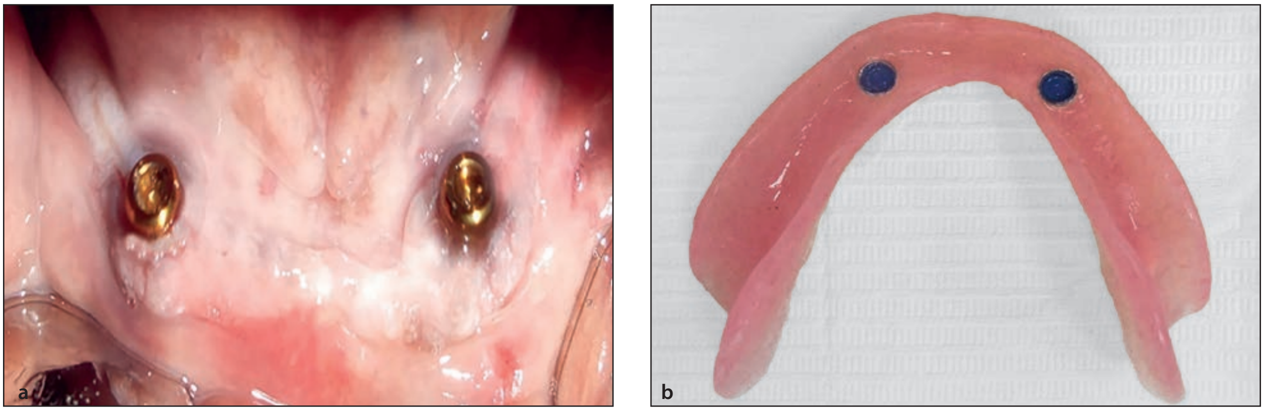

Fig 3 Locator overdentures. *(a)* Locator abutments screwed to the implants. *(b)* The female housing with nylon inserts attached to the denture.

a resilient Dolder bar joint with titanium clips was utilized (Fig 1). For telescopic overdentures, resilient telescopic attachments were used. Ti-base abutments were waxed to form primary crowns (6 mm in height and 4 mm in diameter), cast with gold alloy, and milled (Fig 2). The secondary crowns were constructed from cobalt-chromium above primary crowns with peripheral (0.3 to 0.5 mm) and occlusal (0.5 mm) spaces between the copings to give resiliency and decrease implant overloading.[32] While the patient clenched the posterior teeth in centric occlusion, a disclosing material (Fit Checker) was used to ensure that the contact between the crowns was at the cervical portion only, without contact at the middle or occlusal third of the attachments. This allows for a limited hinge movement and compensates for mucosal resiliency. Also, Fit Checker for dentures was used to ensure optimum contact of the denture with the mucosa and appropriate mucosal compression under load. Frictional snap (Si-tec, Gevelsberg) was used to enhance retention between the crowns. For stud overdentures, very light retentive (blue) inserts were utilized (Fig 3). For all dentures, the balanced occlusal scheme

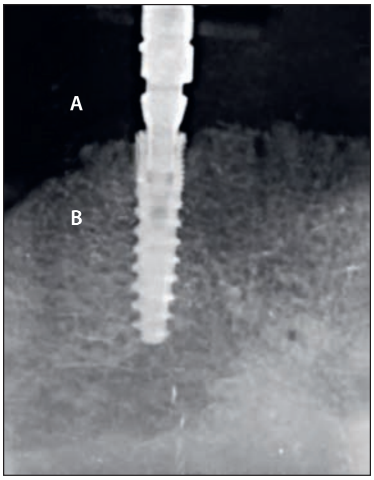

Fig 4 Measurement of marginal bone loss on periapical radiographs.

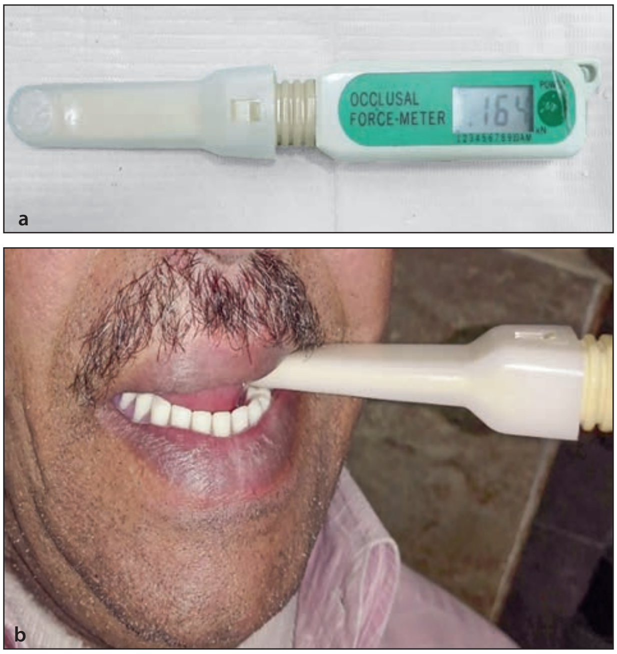

Fig 5 Measurement of maximum occlusal forces. *(a)* The occlusal force meter device. *(b)* The device position during measurement.

Fig 6 Isolated strain gauges attached to the polished surface of the denture.

was used. The detailed prosthetic procedures were described elsewhere.[25]

Evaluation of Marginal Bone Loss

Standardized digital periapical radiographs (Digora Optime, Orion Corp/Soredex) were used to measure marginal bone loss. An individualized film holder for each patient was made to ensure that the holder was positioned identically between baseline and 1-year acquisitions. The film holder was fixed to the implants using the placement tool for standardization of the film position.[33,34] The x-ray machine (de Götzen) operated at 70 kVp and 8 mA. The resultant images were standardized for dimensions (40-µm pixel size, 900 × 641 pixels, and 8 bits), brightness, and contrast and traced using the device software. Marginal bone loss was evaluated as the difference in bone height between baseline and after 12 months of insertion. The bone height is the distance between the implant platform (A) and first bone-to-implant contact (B; Fig 4).[25,35] Bone loss was evaluated at mesial and distal aspects, and the average was used in the analysis. Three calibrated examiners (E.M.A, H.M.H, A.R.M) performed the measurements.[25] Bone loss was also evaluated intrapersonally (three times on the same day).

Evaluation of Maximum Occlusal Force

Maximum occlusal forces were evaluated using a digital bite-force meter (Nagano Keiki; Fig 5). The device has a disposable polyvinyl cap for biting, which is positioned over a bite fork. The device fork was placed between the artificial teeth in the areas of the first molars.[18] Patients were informed to bite as hard as possible on the device for a few seconds. The test was performed three times with a 1-minute rest between each reading, and the mean was used. The occlusal force measurements on both sides were averaged and subjected to statistical analysis.

Evaluation of Denture Base Deformation

Four strain-gauges (resistance: 119.6 ± 0.4% Ω; gauge length: 1 mm; gauge factor: 2.08% ± 1.0%, Kyowa) were fixed to the lingual surface of the dentures (two gauges opposite the implant attachment on the right and left side and two gauges located 5 mm below them) using an adhesive provided by the manufacturer (CC-33A).[23,31] The wires of the gauges were fixed to the polished surface of the denture using an adhesive. Calibration of the strain gauges was done before the experiment was performed. The fine wires of the gauges were isolated from saliva with a chloroprene rubber (HAMATITE-Y; Fig 6). Each gauge was connected to a dummy gauge (fixed on an acrylic plate) in 1/2 Wheatstone bridge. The dummy gauge is located internally in a multichannel strainmeter (Tinsley). Strain registrations were made

Table 2 Comparison of Marginal Bone Loss, Maximum Occlusal Force, and Denture Strains Between Groups

	Marginal bone loss (in mm)		Maximum occlusal force (in N)		Denture strains (in με)	
	Mean	SD	Mean	SD	Mean	SD
Bar overdentures	0.44	0.13	132.02	7.42	287.17	98.19
Telescopic overdentures	0.49	0.10	146.65	7.50	157.25	28.21
Stud overdentures	0.30	0.07	123.34	6.52	92.68	23.22
ANOVA *P* value	< .001*		< .001*		< .001*	
Bar overdentures–telescopic overdentures[#]	.227		< .001*		.001*	
Bar overdentures–stud overdentures[#]	.003*		.005*		< .001*	
Telescopic overdentures–stud overdentures[#]	.000*		< .001*		.014*	

**P* is significant at .05 level. [#]*P* value of pairwise comparison between each two groups (Bonferroni test).

during maximum clenching. Each patient exerted five clenches, and the highest microvolt value (μV) was selected. The mean absolute μV values of the four channels were detected and then converted into microstrain (με) using the formula: strain (ε)= 4 V_{out}/V_{in} GF, where, V_{out} is output voltage (0.577V) and V_{in} is the measured (input) voltage, and GF is the gauge factor (GF = 2.0). For standardization and simplification of measurements, the maximum occlusal force and denture strains were calculated 12 months after overdenture insertion.

Statistical Analysis

An analysis of variance (ANOVA) test was utilized to compare marginal bone loss, maximum occlusal force, and denture strains between groups followed by the Bonferroni method for multiple comparisons. Multiple linear regression analysis (with the stepwise method) was adopted to study the relation between marginal bone loss and other confounding variables (age, sex, number of previous dentures, bone height in the interforaminal region, time of edentulism, attachment type, maximum occlusal force, and denture strains). $P < .05$ was considered significant.

RESULTS

Forty-six men and 44 women (aged from 45 to 70 years) were investigated. Comparisons of baseline characteristics of the different groups are presented in Table 1 ($P > .05$, Table 1). Two implants failed in two subjects in bar overdentures. The implant survival rates were 96.6% (bar overdentures), 100% (telescopic overdentures), and 100% (stud overdentures) without significant difference (log-rank test, $P = .134$). Intraclass correlation coefficients for marginal bone loss were > 0.80.

Marginal bone loss, maximum occlusal force, and denture strains significantly differed between groups ($P < .001$, Table 2). Multiple comparisons between each two groups are presented in the same table. Telescopic overdentures demonstrated the highest bone loss, followed by bar overdentures, and stud overdentures showed the lowest bone loss. The difference in bone loss between bar overdentures and telescopic overdentures was not significant. Telescopic overdentures demonstrated the highest maximum occlusal force, followed by bar overdentures, and stud overdentures showed the lowest maximum occlusal force. The highest denture strains were noted with bar overdentures, followed by telescopic overdentures, and stud overdentures showed the lowest denture strains.

In the multiple regression model, age (coeff. = –0.008; SE = 0.003; $t = -2.384$; $P = .022$; 95% CI = –0.014 to –0.001), bone height in the interforaminal region (coeff. = 0.011; SE = 0.004; $t = 2.386$; $P = .023$; 95% CI = 0.002 to 0.019), number of previous dentures (coeff. = –0.082; SE = 0.026; $t = -3.096$; $P = .004$; 95% CI = –0.135 to –0.028), maximum occlusal force (coeff. = 0.0062; SE = 0.001; $t = 6.976$; $P \leq .001$; 95% CI = 0.004 to 0.008), and denture strains (coeff. = 0.00029; SE = 0.000; $t = 2.040$; $P = .048$; 95% CI = 0.000 to .001) were significantly correlated with bone loss (Table 3). Sex, time of edentulism, and attachment type did not demonstrate a significant correlation with bone loss. These confounding variables were excluded, and the final model is presented in Table 4. For every 1-year increase in age, there was a decrease in bone loss by 0.3% (0.003 mm; SE = 0.002; $t = -2.192$; $P = .034$; 95% CI = –0.007 to 0.000). The effect of bone height in the interforaminal region was that for every 1-mm increase in bone height, there was an increase in bone loss by 1% (0.01 mm; SE = .004; $t = 2.308$; $P = .026$; 95% CI = 0.001 to 0.019). The effect of number of previous dentures was that for every one increase in number of worn dentures, there was a decrease in bone loss by 4.2% (0.042 mm; SE = 0.004; $t = 2.308$; $P = .026$; 95% CI = 0.001 to 0.019). The effect of maximum occlusal

Table 3 Multiple Linear Regression Analysis of All Confounding Variables Affecting Marginal Bone Loss

					95% CI	
	Coefficient B	Standard error (SE)	*t*	*P*	Lower	Upper
Age	–0.008	0.003	–2.384	.022*	–0.014	–0.001
Sex	0.095	0.054	1.766	.085	–0.014	0.204
Bone height in the interforaminal region	0.011	0.004	2.386	.023*	0.002	0.019
No. of previous dentures	–0.082	0.026	–3.096	.004*	–0.135	–0.028
Time of edentulism	0.011	0.017	.624	.536	–0.024	0.045
Attachment type	0.009	0.017	.509	.613	–0.026	0.044
Maximum occlusal force	0.0062	0.001	6.591	< .001*	0.004	0.008
Denture strains	0.00029	0.000	2.040	.048*	0.000	0.001

**P* is significant at .05 level.

Table 4 Final Model Including Significant Confounding Variables Only

					95% CI	
	Coefficient B	Standard error (SE)	*t*	*P*	Lower	Upper
Age	–0.003	0.002	–2.192	.034*	–0.007	0.000
Bone height in the interforaminal region	0.010	0.004	2.308	.026*	0.001	0.019
No. of previous dentures	–0.042	0.014	–2.992	.005*	–0.070	–0.014
Maximum occlusal force	0.0064	0.001	6.976	< .001*	0.005	0.008
Denture strains	0.00021	0.00008	2.472	.017*	0.00004	0.00040

**P* is significant at .05 level.

force was that for every 10-N increase in maximum occlusal force, there was an increase in bone loss by 6.4% (0.064 mm; SE = .001; $t = 6.976$; $P < .001$; 95% CI = 0.005 to 0.008). The effect of denture strain was that for every 10-με increase in denture strains, there was an increase in bone loss by 0.21% (0.0021 mm; SE = 0.00008; $t = 2.472$; $P < .017$; 95% CI = 0.00004 to 0.0004).

DISCUSSION

Marginal bone loss was evaluated after 1 year only, as it has been reported that the majority of bone loss occurred in the first year after implant loading.[36] Another reason is to eliminate the effect of time on marginal bone loss and to simplify the statistical model, as the correlation between bone loss and time was small.[37] Overall, the null hypothesis was rejected, as there was a significant correlation between marginal bone loss and several confounding factors (age, bone height in the interforaminal region, number of previous dentures, maximum occlusal force, and denture strains). For all groups, the range of marginal bone loss (0.30 to 0.49 mm) after 1 year was similar to that obtained by Gotfredsen and Holm,[38] who reported 0.6 mm marginal bone loss with overdentures loaded conventionally after 1 year. This range is lower than the normal range (1 mm after 12 months), which occurs as a result of bone adaptation to functional stresses.[36] This could be attributed to the platform-switching design of the implants used, which minimizes stresses in the peri-implant crestal bone.[5] Moreover, the flapless surgical protocol reduces the bone loss that might occur due to stage-two surgery and abutment connection.[39] However, as in many studies, marginal bone loss that occurred between implant placement and overdenture delivery was not evaluated. The increased bone loss with telescopic overdentures may be due to increased vertical height of the attachment, which may create a vertical cantilever and increase implant micromotions.[25] Moreover, the cervical tight fit between the inner and outer crowns may increase the retention, stability, and rigidity of the attachment.[8] Similarly, another study[32] noted increased horizontal forces and movement of the mandibular denture during chewing in patients wearing telescopic overdentures. Such forces may increase moment load transmission to the implants. The resiliency and reduced profile of the locator attachment reduces the implant stresses created by the vertical cantilever and minimizes bone loss. In line with this explanation, Akça et al[39] found reduced marginal bone loss with locator compared with ball anchors for early-loaded implants supporting mandibular overdentures. Therefore, stud overdentures are recommended to preserve alveolar bone rather than bar overdentures and telescopic overdentures.

Maximum occlusal force significantly differed between tested attachments. A similar finding was observed by van Kampen et al,[40] who found that ball attachments recorded significantly higher maximum occlusal force than bar/clip and magnetic attachments. Also, Elsyad and Khairallah[18] found a significantly higher maximum occlusal force with telescopic overdentures compared with bar overdentures. In contrast, Bilhan et al[19] showed no significant effect of attachment type on maximum occlusal force in patients wearing mandibular overdentures retained by two implants. The increased occlusal forces with telescopic overdentures compared to other attachments agrees with the finding of Heckmann et al,[8] who reported a significant increase in masticatory ability and manual dexterity when telescopic attachments were utilized. This may be due to the excellent retention and stability of telescopic overdentures, which improve muscle activity,[41] increase the maximum occlusal force,[42,43] and increase food comminution. The enhanced retention, stability, and vertical height of telescopic attachments may lead to increased axial transmission of masticatory force and generation of extensive occlusal forces before triggering of periosteal mechanoreceptors adjacent to the dental implant, which may increase maximum occlusal force.[44] The reduced maximum occlusal force with bar overdentures and stud overdentures compared with telescopic overdentures may be due to the resiliency and reduced vertical height of these attachments.[18]

Regarding denture strains, the attachments may act as a fulcrum during clenching posterior teeth due to mucosal compressibility. This fulcrum increases denture strain opposite the abutments and may lead to denture base fracture.[24] The different vertical heights of the bar, telescopic, and locator attachments may be responsible for the difference in denture strain and deformation among the attachment types. The increased denture strains with bar overdentures could be due to the large size (height and width) of bar abutments, which occupy more space in the denture and cause more thinning of denture acrylic resin opposite the abutments.[23] In addition, the contact between the denture and the bar abutments creates a fulcrum during clenching. Thus, the denture is prone to more deformation.[45] Although telescopic crowns are large and occupy more prosthetic space than bar attachments, denture strains were lower with telescopic overdentures than bar overdentures. This could be attributed to the vertical resiliency of the telescopic crowns provided by the occlusal and circumferential relief between the crowns, which allow complete denture settling without rotation on a fulcrum.[23] Also, locator attachments have reduced vertical profile and increased vertical resiliency. This enhances settlement of the denture base and reduces denture deformation and strains.[24] Therefore, reinforcement of the denture base for bar attachments may be recommended rather than telescopic or locator attachments to reduce the possibility of denture base deformation and fracture.

The absence of correlation between bone loss and attachment type was in line with several systematic reviews,[15–17] in which the authors found no effect of attachment type on bone loss of implants assisting mandibular overdentures. Also, the lack of correlation between marginal bone loss and sex was in line with several studies.[46,47] Longer periods of edentulism are associated with more residual ridge resorption, and implants are placed in the basal bone, which may reduce the rate of marginal bone loss.[29] However, in this study, a significant relationship between the period of edentulism and bone loss was not found.

The most interesting finding of this study was the significant relation between marginal bone loss and several confounding factors. The increase in age and number of previously worn dentures was significantly associated with a decrease in marginal bone loss. Also, the increase in bone height in the interforaminal region was significantly associated with an increase in marginal bone loss. These findings may be explained by several reasons. The increase in patient age is usually associated with long periods of edentulism in which residual ridge resorption occurred and bone height in the interforaminal region decreased. With increased ridge resorption, the patients usually seek prosthetic care for denture relining or making new dentures. The increase in the number of dentures worn before implant treatments usually indicates that these patients were unsatisfied with the retention and stability of conventional dentures and believe that making new dentures will solve the problem.[48] The denture instability will induce more ridge resorption.[49] After resorption of the alveolar bone of the ridge, the process terminates at the basal bone. Such bone is predominantly compact, dense, and less liable to marginal bone loss in the long term.[29] It has been generally accepted that once the denture comes to rest mostly on basal mandibular bone, the rate of bone resorption reduces.[5,50] In line with this finding, another study reported that sites with poorer bone quality may statistically affect marginal bone loss and implant failure rates.[51]

The increase in maximum occlusal force was significantly associated with an increase in marginal bone loss. Similarly, Geckili et al[21] found that bone loss around implants supporting mandibular overdentures was significantly increased by an increase in maximum occlusal force. Lindquist and associates reported that factors causing increased occlusal loading were associated with increased marginal bone loss.[52] The high occlusal forces may create increased peri-implant stresses, which in turn create higher bone loss.[21] In contrast to these findings, van Kampen et al[22] could not demonstrate a relationship between maximum occlusal force and marginal bone loss in patients wearing mandibular implant overdentures. The marginal bone loss increased significantly with the increase in denture strains. This suggests that increased denture base deformation was associated with an increase in bone loss. This finding may signify the importance of providing denture base reinforcement, especially over the implant attachments (where most denture strains occur) to minimize denture strain and deformation. The reinforcement also provides better load distribution on the implants and the supporting ridges and may reduce marginal bone loss.[53] In line with this finding, Takahashi et al[54] found reduced peri-implant stresses after reinforcement of the maxillary overdenture regardless of the denture design. They added that reinforcements can make the denture base more rigid and less deformable, which contributes to extend the longevity of prostheses and implants. Moreover, Tokgoz et al[55] found that reinforcement of the bar-implant mandibular overdentures with glass fiber or Co-Cr cast metal can substantially increase fracture strength compared with nonreinforced overdentures. Also, Özçelik et al[56] concluded that metal reinforcement for implant-retained mandibular overdentures reduces stress in the anterior area of the prosthesis and minimizes the incidence of fracture.

The limitations of this study include the lack of standardization of attachment height within the same group or between different groups to make all attachments at the same vertical cantilever distance from the mucosa. Standardization of the dimensions of bar and telescopic attachments may be possible using precise CAD/CAM constructed patterns and wax-lost casting technology. However, this was difficult to achieve practically and was not performed in this study due to the variability of restorative and interarch spaces between participants. Moreover, telescopic attachments usually require increased vertical height (at least 6 mm) to obtain sufficient retention. To achieve standardization between attachments, the vertical height of the bar and locator attachments should be unnecessarily increased. This may transmit increased forces to the implants by increasing the vertical cantilever. Therefore, in the present study, it was decided to study denture strains, maximum occlusal force, and marginal bone loss for each attachment using the size recommended by the manufacturer and guided by restorative and interarch spaces without standardization of attachment dimensions. Future clinical studies are needed to evaluate the effect of overdenture base reinforcement on denture deformation and strains compared with nonreinforced overdentures.

CONCLUSIONS

Within the limits of this trial, age, mandibular bone height, number of previous dentures, maximum occlusal force, and denture strains were significantly correlated with marginal bone loss. However, sex, time of edentulism, and attachment type did not demonstrate a significant correlation with marginal bone loss.

ACKNOWLEDGMENTS

The authors have stated explicitly that there are no conflicts of interest in connection with this article.

REFERENCES

1. Thomason JM. The use of mandibular implant-retained overdentures improve patient satisfaction and quality of life. J Evid Based Dent Pract 2010;10:61–63.
2. Trakas T, Michalakis K, Kang K, Hirayama H. Attachment systems for implant retained overdentures: A literature review. Implant Dent 2006;15:24–34.
3. Evtimovska E, Masri R, Driscoll CF, Romberg E. The change in retentive values of Locator attachments and Hader clips over time. J Prosthodont 2009;18:479–483.
4. Porter JA Jr, Petropoulos VC, Brunski JB. Comparison of load distribution for implant overdenture attachments. Int J Oral Maxillofac Implants 2002;17:651–662.
5. Maeda Y, Miura J, Taki I, Sogo M. Biomechanical analysis on platform switching: Is there any biomechanical rationale? Clin Oral Implants Res 2007;18:581–584.
6. Elsyad MA. Soft liner/clip attachment for bar-retained implant overdentures: A technical note. J Oral Implantol 2016;42:442–445.
7. 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;26:195–202.
8. Heckmann SM, Schrott A, Graef F, Wichmann MG, Weber HP. Mandibular two-implant telescopic overdentures. Clin Oral Implants Res 2004;15:560–569.
9. Lee CK, Agar JR. Surgical and prosthetic planning for a two-implant-retained mandibular overdenture: A clinical report. J Prosthet Dent 2006;95:102–105.
10. Nguyen CT, Masri R, Driscoll CF, Romberg E. The effect of denture cleansing solutions on the retention of pink Locator attachments: An in vitro study. J Prosthodont 2010;19:226–230.
11. Saravi BE, Putz M, Patzelt S, Alkalak A, Uelkuemen S, Boeker M. Marginal bone loss around oral implants supporting fixed versus removable prostheses: A systematic review. Int J Implant Dent 2020;6:20.
12. Misch CE, Perel ML, Wang HL, et al. Implant success, survival, and failure: The International Congress of Oral Implantologists (ICOI) Pisa consensus conference. Implant Dent 2008;17:5–15.
13. Galindo-Moreno P, León-Cano A, Ortega-Oller I, Monje A, O'Valle F, Catena A. Marginal bone loss as success criterion in implant dentistry: Beyond 2 mm. Clin Oral Implants Res 2015;26:e28–e34.
14. Qian J, Wennerberg A, Albrektsson T. Reasons for marginal bone loss around oral implants. Clin Implant Dent Relat Res 2012;14:792–807.
15. Gonçalves F, Campestrini VLL, Rigo-Rodrigues MA, Zanardi PR. Effect of the attachment system on the biomechanical and clinical performance of overdentures: A systematic review. J Prosthet Dent 2020;123:589–594.
16. Leão RS, Moraes SLD, Vasconcelos BCE, Lemos CAA, Pellizzer EP. Splinted and unsplinted overdenture attachment systems: A systematic review and meta-analysis. J Oral Rehabil 2018;45:647–656.

17. Cehreli MC, Karasoy D, Kökat AM, Akça K, Eckert S. A systematic review of marginal bone loss around implants retaining or supporting overdentures. Int J Oral Maxillofac Implants 2010;25:266–277.
18. Elsyad MA, Khairallah AS. Chewing efficiency and maximum bite force with different attachment systems of implant overdentures: A crossover study. Clin Oral Implants Res 2017;28:677–682.
19. Bilhan H, Geckili O, Mumcu E, Cilingir A, Bozdag E. The influence of implant number and attachment type on maximum bite force of mandibular overdentures: A retrospective study. Gerodontology 2012;29:e116–e120.
20. Uçankale M, Akoğlu B, Özkan Y, Ozkan YK. The effect of different attachment systems with implant-retained overdentures on maximum bite force and EMG. Gerodontology 2012;29:24–29.
21. Geckili O, Mumcu E, Bilhan H. The effect of maximum bite force, implant number, and attachment type on marginal bone loss around implants supporting mandibular overdentures: A retrospective study. Clin Implant Dent Relat Res 2012;14(suppl 1):e91–e97.
22. van Kampen F, Cune M, van der Bilt A, Bosman F. The effect of maximum bite force on marginal bone loss in mandibular overdenture treatment: An in vivo study. Clin Oral Implants Res 2005;16:587–593.
23. ELsyad MA, Fathe Mahanna F, Samir Khirallah A, Ali Habib A. Clinical denture base deformation with different attachments used to stabilize implant overdentures: A crossover study. Clin Oral Implants Res 2020;31:162–172.
24. ELsyad MA, Errabti HM, Mustafa AZ. Mandibular denture base deformation with locator and ball attachments of implant-retained overdentures. J Prosthodont 2016;25:656–664.
25. ELsyad MA, Denewar BA, Elsaih EA. Clinical and radiographic evaluation of bar, telescopic, and locator attachments for implant-stabilized overdentures in patients with mandibular atrophied ridges: A randomized controlled clinical trial. Int J Oral Maxillofac Implants 2018;33:1103–1111.
26. Cawood JI, Howell RA. A classification of the edentulous jaws. Int J Oral Maxillofac Surg 1988;17:232–236.
27. Lekholm U, Zarb G. Patient selection and preparation. In: Bränemark PI, Zarb G, Albrektsson T (eds). Tissue-Integrated Prostheses: Osseointegration in Clinical Dentistry. Chicago: Quintessence, 1985: 199–209.
28. Ahuja S, Cagna DR. Defining available restorative space for implant overdentures. J Prosthet Dent 2010;104:133–136.
29. Ma S, Tawse-Smith A, Thomson WM, Payne AG. Marginal bone loss with mandibular two-implant overdentures using different loading protocols and attachment systems: 10-year outcomes. Int J Prosthodont 2010;23:321–332.
30. Zielhuis GA, Straatman H, van 't Hof-Grootenboer AE, van Lier HJ, Rach GH, van den Broek P. The choice of a balanced allocation method for a clinical trial in otitis media with effusion. Stat Med 1990;9:237–246.
31. Elsyad MA, El-Waseef FA, Al-Mahdy YF, Fouad MM. A comparison of mandibular denture base deformation with different impression techniques for implant overdentures. Clin Oral Implants Res 2013;24(suppl A100):127–133.
32. Heckmann SM, Winter W, Meyer M, Weber HP, Wichmann MG. Overdenture attachment selection and the loading of implant and denture-bearing area. Part 2: A methodical study using five types of attachment. Clin Oral Implants Res 2001;12:640–647.
33. Elsyad MA, Elsaih EA, Khairallah AS. Marginal bone resorption around immediate and delayed loaded implants supporting a locator-retained mandibular overdenture. A 1-year randomised controlled trial. J Oral Rehabil 2014;41:608–618.
34. Elsyad MA, Mahanna FF, Elshahat MA, Elshoukouki AH. Locators versus magnetic attachment effect on peri-implant tissue health of immediate loaded two implants retaining a mandibular overdenture: A 1-year randomised trial. J Oral Rehabil 2016;43:297–305.
35. Elsyad MA, Khirallah AS. Circumferential bone loss around splinted and nonsplinted immediately loaded implants retaining mandibular overdentures: A randomized controlled clinical trial using cone beam computed tomography. J Prosthet Dent 2016;116:741–748.
36. Albrektsson T, Zarb G, Worthington P, Eriksson AR. The long-term efficacy of currently used dental implants: A review and proposed criteria of success. Int J Oral Maxillofac Implants 1986;1:11–25.
37. Hasegawa M, Hotta Y, Hoshino T, Ito K, Komatsu S, Saito T. Long-term radiographic evaluation of risk factors related to implant treatment: Suggestion for alternative statistical analysis of marginal bone loss. Clin Oral Implants Res 2016;27:1283–1289.
38. Gotfredsen K, Holm B. Implant-supported mandibular overdentures retained with ball or bar attachments: A randomized prospective 5-year study. Int J Prosthodont 2000;13:125–130.
39. Akça K, Çavuşoğlu Y, Sağirkaya E, Çehreli MC. Early-loaded one-stage implants retaining mandibular overdentures by two different mechanisms: 5-year results. Int J Oral Maxillofac Implants 2013;28:824–830.
40. 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 2002;81:170–173.
41. van Kampen FM, van der Bilt A, Cune MS, Fontijn-Tekamp FA, Bosman F. Masticatory function with implant-supported overdentures. J Dent Res 2004;83:708–711.
42. Zafiropoulos GG, Hoffmann O. Five-year study of implant placement in regenerated bone and rehabilitation with telescopic crown retained dentures: A case report. J Oral Implantol 2009;35:303–309.
43. Hoffmann O, Beaumont C, Tatakis DN, Zafiropoulos GG. Telescopic crowns as attachments for implant supported restorations: A case series. J Oral Implantol 2006;32:291–299.
44. Elsyad MA, Khairallah AS, Shawky AF. Changes in the edentulous maxilla with ball and telescopic attachments of implant-retained mandibular overdentures: A 4-year retrospective study. Quintessence Int 2013;44:487–495.
45. Duncan JP, Freilich MA, Latvis CJ. Fiber-reinforced composite framework for implant-supported overdentures. J Prosthet Dent 2000;84:200–204.
46. van Steenberghe D, Quirynen M, Naert I, Maffei G, Jacobs R. Marginal bone loss around implants retaining hinging mandibular overdentures, at 4-, 8- and 12-years follow-up. J Clin Periodontol 2001;28:628–633.
47. Naert I, Koutsikakis G, Quirynen M, Duyck J, van Steenberghe D, Jacobs R. Biologic outcome of implant-supported restorations in the treatment of partial edentulism. Part 2: A longitudinal radiographic study. Clin Oral Implants Res 2002;13:390–395.
48. Gjengedal H, Berg E, Gronningsaeter AG, et al. The influence of relining or implant retaining existing mandibular dentures on health-related quality of life: A 2-year randomized study of dissatisfied edentulous patients. Int J Prosthodont 2013;26:68–78.
49. ELsyad MA, Mohamed SS, Shawky AF. Posterior mandibular ridge resorption associated with different retentive systems for overdentures: A 7-year retrospective preliminary study. Int J Prosthodont 2017;30:260–265.
50. Wright PS, Glantz PO, Randow K, Watson RM. The effects of fixed and removable implant-stabilised prostheses on posterior mandibular residual ridge resorption. Clin Oral Implants Res 2002;13:169–174.
51. Chrcanovic BR, Albrektsson T, Wennerberg A. Bone quality and quantity and dental implant failure: A systematic review and meta-analysis. Int J Prosthodont 2017;30:219–237.
52. Lindquist LW, Rockler B, Carlsson GE. Bone resorption around fixtures in edentulous patients treated with mandibular fixed tissue-integrated prostheses. J Prosthet Dent 1988;59:59–63.
53. Gibreel MF, Khalifa A, Said MM, et al. Biomechanical aspects of reinforced implant overdentures: A systematic review. J Mech Behav Biomed Mater 2019;91:202–211.
54. Takahashi T, Gonda T, Maeda Y. Can reinforcement of maxillary implant overdentures decrease stress on underlying implants? Int J Oral Maxillofac Implants 2017;32:63–69.
55. Tokgoz S, Ozdiler A, Gencel B, Bozdag E, Isık-Ozkol G. Effects of denture base thicknesses and reinforcement on fracture strength in mandibular implant overdenture with bar attachment: Under various acrylic resin types. Eur J Dent 2019;13:64–68.
56. Özçelik TB, Yılmaz B, Akçimen Y. Metal reinforcement for implant-supported mandibular overdentures. J Prosthet Dent 2013;109:338–340.