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Original Article

A Correlation Study between different Implant Diameters and Cantilever Lengths on the Marginal Bone Loss of Implant Supported Maxillary Prostheses: A Randomized Controlled Trial

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ABSTRACT

Objectives: To report a correlation between the different implant diameter and different cantilever length regarding bone height changes in implant supported maxillary prosthesis.

Materials and methods: Sixteen patients were recruited to receive six implants in the edentulous maxilla. Patients were randomized using sealed envelopes into two groups: Group I received small diameter and Group II with standard diameter. Patients were similarly randomized into sub-groups; Groups IA, IB, IIA and IIB. In Groups IA, IIA, implants were placed with an anterior-posterior AP implant spread to the cantilevers lengths at a ratio of 1:3 while in Group IB, IIB implants were placed at a ratio of 1:2. Cone Beam Computed Tomography (CBCT) was performed at the day of prosthesis delivery, after 4, 8 and 24 month follow up to measure the marginal bone height changes. Spearman`s correlation coefficient was used to correlate between bone height and different implant diameters and cantilever lengths. The significance level was set at $P \leq 0.05$.

Results: A weak positive insignificant correlation was found between the different cantilever length and the small and standard implant diameter.

Conclusion: Both the standard and small implant diameter with different cantilever length showed marginal bone height changes within the physiologic limit for implant supported maxillary prosthesis.

INTRODUCTION

Implant supported prosthesis have been a reliable treatment modality with long term survival rates and further improvement the quality of life for completely and partially edentulous patients[1]. The use of implants especially in completely edentulous patients offered several advantages such as longevity, improved in all functions, bone preservation and better psychological results[2].

The use of narrow diameter implants will provide a reliable minimally invasive[4] alternative to augmentation techniques which are time consuming and would require a great surgical experience to reduce patients' morbidity and prevent complications such as postoperative pain, infections, nerve damage, bone fractures, hemorrhage, wound dehiscence and implant or augmentation failures. Narrow dental implants have been classified according to Klein et al [3] into;

Category 1: <3.0 mm ("mini-implants"), Category 2: 3.0–3.25 mm, Category 3: 3.30–3.50 mm. Schiegnitz and Al-Nawas [4] concluded in their systematic review that there was no significant difference in survival rates between narrow implants of category 2 and standard implant[4].

The definition of a cantilever, according to the Glossary of Prosthodontics terms, is a fixed bridge with a free end that is supported and retained only on one end by one or more abutments[5]. It was suggested that the length of the cantilever should be limited to the size of two teeth after the last implant in the mandible, and only one tooth in the maxilla, in order to reduce the forces transmitted to the implants and the underlying bone[6]. Several authors reported that excessively long cantilevers will increase the risk of prosthetic complications [5-10]. Shackleton et al. evaluated two cantilever lengths (≤ 15 mm and > 15 mm) for fixed prostheses on implants and concluded that short cantilevers had better clinical performance than long cantilevers[11]. Sertgöz et al. concluded that an increase in cantilever length will result in higher values of stress at the implant interface[7]. The incorporation of the cantilever in implant supported prosthesis will increase the magnitude of forces on the crestal bone around the implants, and this overload is proportional to the length of the cantilever [5,6,9,10,12].

One of the long-term clinical evaluations to determine successful osseointegration is recording the marginal bone height changes around the implants. Changes in marginal bone levels that are beyond the physiologic limits would result in loss of bone height around the anchoring implant. Bone loss of about 1.5mm after the first year of loading with an additional 0.2mm amount of bone loss per year is measured to be within the physiologic limits [13,14].

The aim of this randomized clinical trial is to determine if there is a correlation between the different implant diameter and different cantilever length regarding changes in bone height in implant supported

MATERIALS AND METHODS

Sixteen male patients were selected from the outpatient clinic of the Prosthodontics Department , Faculty of Oral and Dental Medicine, Cairo University. Patients were selected following a strict inclusion criterion: a completely edentulous maxillae showing normal maxillo-mandibular relationship (Class I Angle classification), with no para-functional habits and systemically free from any medical conditions. The minimum accepted ridge width was 4.5mm bucco-lingually, and the minimum accepted ridge height was 13mm anteriorly and 10mm posteriorly.

Patients who met the inclusion criteria signed the consent form according to the ethical principles stated in Helsinki Declaration (https://www. wma.net) indicating their approval to be involved in this study and undergoing surgical procedures of implant placement. Ethical approval was also obtained from the Ethical Approval Committee in the Faculty of Dentistry, Cairo University.

Sample size calculation

Khorshid et al. compared the bone height changes between two different diameters with different cantilever length after 24 month follow up period [15]. In patients receiving screw retained prosthesis with a ratio of 1:2 cantilever length using standard implant diameter(3.7mm), bone height changes were recorded to be 1.33±0.24mm. A clinical important difference based on expert opinion = 0.4., this is the least acceptable difference between the two groups[15]. Independent-t-test with a power of 80% and

0.05 alpha significance was used for sample size calculation, and 7 patients were reported in each group, with a total of 14 patients. 10% was added to compensate for dropouts with 8 patients per group with a total of 16 patients.

A total of 96 implants were placed in sixteen patients over which screw retained implant supported maxillary prosthesis were fabricated. The patients were randomized using sealed envelopes into two groups: Group I received small diameter 3.0 mm implants and Group II received standard diameter 3.7mm implants. Patients in each group were further randomized using sealed envelopes into two sub-groups: IA, IB, IIA and IIB. In Groups IA and IIA, implants were placed with an anterior-posterior AP implant spread to the cantilever lengths (CL: AP) at a ratio of 1:3 while in Groups IB and IIB, implants were placed with an anterior-posterior AP implant spread to the cantilever lengths (CL: AP) at a ratio of 1:2.

Conventional maxillary complete dentures were fabricated for all included patients with an adaptation period of 6 weeks. The maxillary dentures were duplicated to obtain radio-opaque scan appliances. Duplication was performed using a mixture of amalgam powder and transparent self-cured acrylic resin powder. A Cone Beam Computed Tomographic (CBCT) was performed for all patients while wearing the radiographic scan appliance using the **Scanora 3D Soredex, Helsinki, Finland** machine. All patients were instructed to wear their appliances and to stabilize it in place by biting on an occlusal index constructed for each patient, separating the mandibular teeth from the stent. DICOM files obtained from the CT scan were loaded into the Mimics software (Mimics, Materialise HQ, Technologielaan 15, 3001 Leuven, Belgium) whereby coronal and sagittal reformatting and panoramic views were obtained. The desired implant sites were identified through the radiolucent channels that were previously prepared in the radiographic scan appliance at the midline of each tooth. The bone volumes at each of the six potential sites were evaluated for sufficient bone height, width and density.

For each patient, six implants were planned in the lateral incisor/Canine region, first premolar and first molar region according to the available bone height and width. All Implants were with standardized height; 13 mm for the four anterior implants and 10 mm for the posterior implants. The virtual STL files of the implants were imported into the MIMICS software and then virtual planning was performed at the proposed implant sites.

The base of the radiographic stent was separated from the bone and teeth using the segmentation process. The created mask of the base was grown to a 3D object and then united with the supra bony portion of the implant model using the "Boolean operation" tool. The resultant object is the 3D virtual stent which was exported as an STL (Sterolithiographic) file for 3D printing machine (**Invision Si2, USA**) to build the stent from a photo curable resin material. Metallic sleeves were fitted into the designed holes of the fabricated stent. The surgical stent was then tried in the patient's mouth to check for stability and adaptation.

Implant Installation

Before starting implant installation, the peri-oral region of the patient was wiped by Betadine antiseptic solution, and the computer guided stent was disinfected with a suitable dis-infectant.

The surgical guide was fixed in place using three fixation screws. Osteotomies were then prepared using the classical drilling sequence (pilot, intermediate and final drills) and were irrigated with sterile saline after each drill. For every drill a specially designed "drill guide" was used ***(Figure 1a, 1b)*****.** The

implants were inserted manually through the stent till further tightening was completed with a ratchet using a depth controlling implant driver**.** The primary stability of each implant was measured using the "Osstell" ISQ device (**Osstell AB, Gamlestadsvägen 3B, SE415 02, Sweden)**. The patient's denture was modified using a soft liner and then allowed to heal from 4 to 6 month.

After 4-6 months, the patients were recalled, and the implant stability (ISQ) was recorded using the Osstell device. The snap-on implant plastic transfer copings were placed over each implant and preliminary impression were then taken using a closed tray technique with medium body rubber base impression material. The implant analogues (**ImplantDirect™ LLC Spectra-System Dental Implants**) Calabasas Hills CA, USA) were then snapped on over the plastic transfer copings inside the impression and then the impression was poured using hard stone.

Temporary Titanium abutments were then screwed over the implant analogues within the primary cast and then splinted together using DuraLay resin material (**DuraLay™, Reliance, Dental MFG Co. Worth, IL, USA)** to construct a verification jig. The verification jig was then tried in the patient's mouth and screwed over the implants. The passive fit was checked using the one screw test and using an intraoral explorer. In cases of non-passive areas of the framework, the framework was sectioned and then re-connected intra-orally again using Dura-lay. After complete setting of the Dura-lay, passive fit was then checked finally.

The radiographic stents were then modified by opening windows at areas of the implants and used as a special tray. An open tray impression technique was then performed and again the implant analogues were screwed over the temporary titanium abutments. After pouring of the master cast, plastic castable abutments (**Plastic burnoutsImplants, ImplantDirect™ LLC Spectra-System Dental Implants Calabasas Hills CA, USA)** were fastened to the analogues. The plastic abutments were connected with Dura-lay resin to form a rigid frame. The pattern was invested and cast into chrome cobalt alloy.

Bite registration was then performed using the Wax wafer registration method. Acrylic teeth were set on the framework following the IPO guidelines in accordance with **Misch's** [16]recommendations. Visio-lign Veneering (Visio-lign, Bredent GmbH & Co.KG, WeissenhornerSenden, Germany) light cured system was used to construct the gingiva using a free-hand technique.

The frameworks for both groups were checked individually for fit and passivity using the one screw test. The detection of any gap was an indication that sectioning with a disc, and fastening separately to the implants, re-connecting with Dura-lay resin and soldering (or welding) was required.

In this study, each patient's anterior-posterior AP spread to the cantilever ratio was measured using a ruler on the patient's cast. ***(Figure 2)***. The lengths of the cantilevered segments of the definitive prostheses were measured with a Boley gauge after all finishing and polishing procedures were accomplished, just prior to insertion. The length of the cantilever segments were fabricated for each case according to the group that they were sorted in from the beginning and according to the AP spread measurement recorded. The measurements were made from the distal surface of the most distal implants on both sides to the distal surfaces of the interim prosthesis on both sides. The AP spread was measured on the master casts by laying two straight rulers across the screw access openings of the anterior and posterior abutment analogs; right anterior abutment

analog to left anterior abutment analog for the anterior line; right posterior abutment analog to the left posterior abutment analog for the posterior line. The distance between these two straight anterior and posterior lines was measured using a mm ruler to obtain the AP Spread.

After the build-up was completed, the screw-retained implant supported prostheses were screwed intra-orally and fine occlusal adjustments were made in both groups ***(Figure 3)*.** The prosthetic screws were tightened to 30Ncm with a torque wrench. The access holes were partially plugged with rubber pieces and completely blocked with light-cured composite resin restorative material.

In this study, each patient performed four follow-up CT scans using CBCT machine (**Scanora 3D Soredex, Helsinki, Finland)**. The CT scans were performed at zero, four, eight and twenty four months after definitive prostheses delivery. The raw DICOM data obtained from the CBCT scanning were imported to a special third party software (**Ondemand 3D, Seoul, South Korea)** for secondary reconstruction and for measurement of bone height around each implants in all groups. Mesial, Distal, Buccal and lingual Bone Height measurements were measured from the apex of each implant to the crestal bone height around each implant. The mean values of the Mesial, distal, buccal and lingual around all implants and in all groups were calculated and tabulated. Results obtained from the data sets were statistically analyzed and compared to each other ***(Figure 4)***. The numbers obtained were then tabulated and statistically analyzed.

Statistical analysis was performed using SPSS 20®, Graph Pad Prism® and Microsoft Excel 2016. All data were explored for normality by using Shapiro Wilk and Kolmogorov Normality test and presented as mean difference and standard deviation (SD) values. All data were presented in table 1. Correlation between bone height and different implant diameters were calculated by using Spearman`s correlation coefficient. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with IBM SPSS Statistics Version 20 for Windows.

RESULTS

The results of this study were statistically analysed to evaluate the changes that occurred in the supporting structures of the implants placed in the maxilla as a result of using two different implant diameters with two different Cantilever lengths. A total of 96 implants were placed in sixteen patient over which screw retained implant supported maxillary prostheses were fabricated. Each patient received six implants which were nominated from 1 to 6 starting from the right-hand side to the left-hand side of each patient. Bone Height measurements surrounding each implant were evaluated in both groups at zero, four, eight and twenty-four months after definitive prostheses delivery. The recorded mean differences and standard deviation of the peri-implant marginal bone height values in the two groups at different follow up period were shown in table 1 and Figure 5.

The mean values (m) and standard deviation (St.D) of the bone height in Group IA as shown in Table 1 and Figure 5 were 11.4±0.0mm, 10.32±0.0mm, 10.05±0.07mm and 9.05±0.17mm at zero, four, eight and twenty four months of prostheses delivery in this study respectively. The mean values (m) and standard deviation (St.D) of the bone height in Group IB were 11.57±0.06mm, 10.8±0.2mm, 11.15±0.16mm, 7.68±0.14mm at zero, four, eight and twenty four months of prostheses delivery in this study respectively.

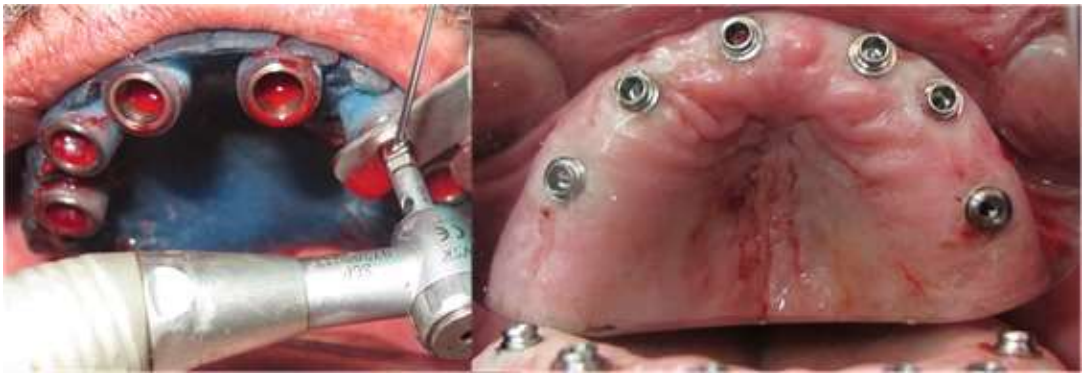

Figure 1a: Osteotomy performed using the classical drilling sequence (pilot, intermediate and final drills)
1b: Implants after being surgically installed and stent retrieval

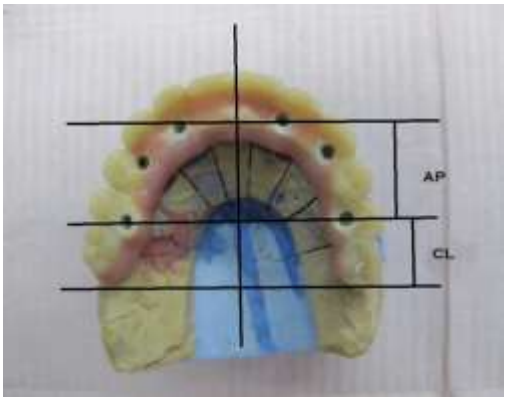

Figure 2: Restoration fabricated on the cast; AP=Antero-posterior Spread and CL=Cantilever Length

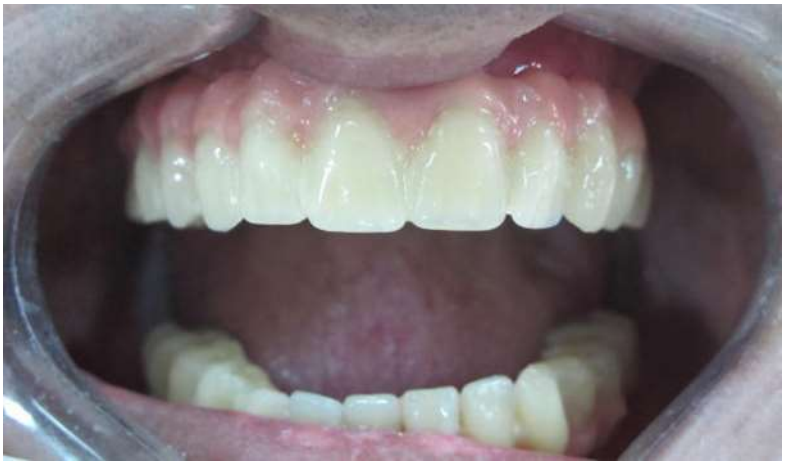

Figure 3: The screw-retained implant supported prostheses delivered in the patient's mouth

The mean values (m) and standard deviation (St.D) of bone height in Group IIA were 11.28±0.27mm, 10.51±0.43mm, 10.49±0.45mm and 10.08±0.9mm at zero, four, eight and twenty four months of prostheses delivery in this study respectively. The mean values (m) and standard deviation (St.D) of the bone height in Group IIB were 11.4±0.0mm, 10.32±0.0mm, 9.97±0.01mm and 9.08±0.12mm at zero, four, eight and twenty four months of prostheses delivery in this study respectively.

Correlation between bone height and different implant diameters were calculated by using Spearman`s correlation coefficient which revealed a positive (+), weak ($r<0.5$), insignificant ($P<0.05$) correlation, as presented in table (2 and Figure 6.

Additionally, Correlation between bone height and different cantilever lengths were calculated by using Spearman`s correlation coefficient which revealed a negative (-), weak ($r<0.5$), insignificant ($P<0.05$) correlation, as presented in table (2) and Figure 7.

DISCUSSION

Generally, the patients who participated in this study reported an improvement of their implant supported prostheses especially when compared to their previous complete dentures. The restorations were highly accepted by the patients due to the restoration being transformed from a removable complete denture to a fixed screw retained implant supported restoration, better masticatory function, increased comfort and elimination of the flanges. They were all able to accommodate efficiently to their restorations immediately after the prostheses delivery. Males were only selected in the following trial to exclude the difference of bone density that may have resulted if females were also selected, as females tends to show changes in bone density due to the hormonal changes and osteoporosis.

All implants in this study included were considered successful in the three groups with different Diameters and CL/AP ratios according to the ICOI (International Congress of Oral Implantologists) Pisa Consensus Conference March 2008[16].

Six implants were placed in each maxilla to ensure a sufficient number to retain maxillary prostheses with larger cantilever lengths. The most distal implant was also placed in the molar region. This was in agreement with a study performed by McAlarney and Stavropoulos[17] who stated that the increase number of implants allowed to use cantilevers safely, as this provides better implant force distribution. They also stated that the position of the most distal implant is an important clinical factor as distal implants placed in the first molar sites is more often clinically preferable than it to be placed in a more anterior position. The more distal the most posterior implant, and the more mesial the most anterior implant, the higher the AP spread and hence the more permissible it is to do more Cantilever Lengths. In this study, a millimeter ruler and a boley gauge was used to measure the A/P spreads and CLs following the same technique used in a study performed by Drago [18].

Correlation analysis between the mean values of the bone height changes and the Cantilever lengths revealed a weak ($r<0.5$), negative correlation which was at an insignificant level ($P<0.05$). This means that the less the cantilevers length to the AP spread ratios as in groups IA and IIA, the less the amount of peri-implant bone loss hence indicating that the amount of AP spread

dictates the maximum lengths of distal cantilevers that can be performed safely.

Table (1): Mean and Standard Deviation of Bone Height Values in all groups at different intervals

bone		Group I		Group II	
		M	SD	M	SD
Baseline	A	11.40	0.00	11.28	0.27
	B	11.57	0.06	11.40	0.00
After 4 months	A	10.32	0.00	10.51	0.43
	B	11.13	0.06	10.32	0.00
After 8 months	A	10.05	0.07	10.49	0.45
	B	8.55	0.16	9.97	0.01
After 24 months	A	9.05	0.17	10.08	0.90
	B	7.68	0.14	9.08	0.12

Table (2): Spearman`s correlation coefficient between bone height and implant length and between bone height and cantilever length

Correlation	r	P value	Indication
Implant diameter and Bone Height	+0.11	0.47	weak / positive /insignificant
Cantilever Length and Bone Height	-0.12	0.47	weak / negative /insignificant

r: Spearman's correlation coefficient

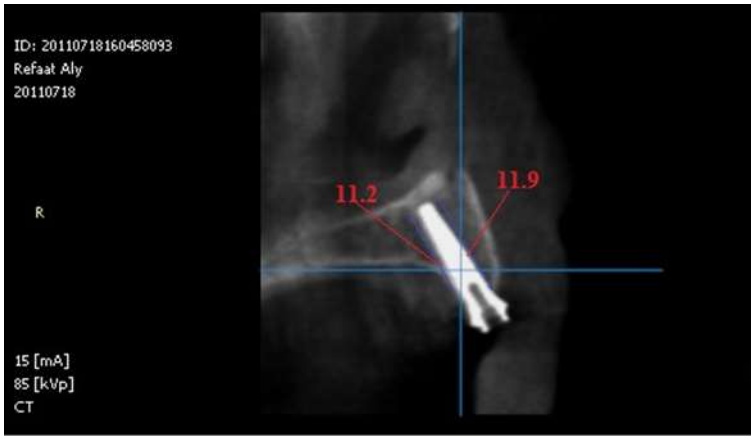

Figure 4: Buccal and Lingual Bone Height measurements

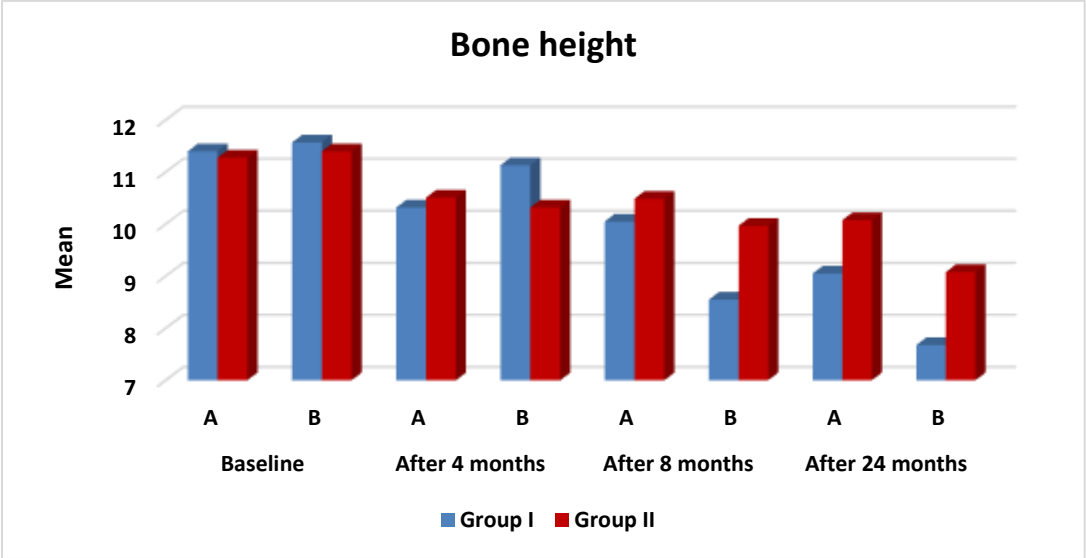

Figure (5): Bar chart showing bone height results in all groups at different intervals.

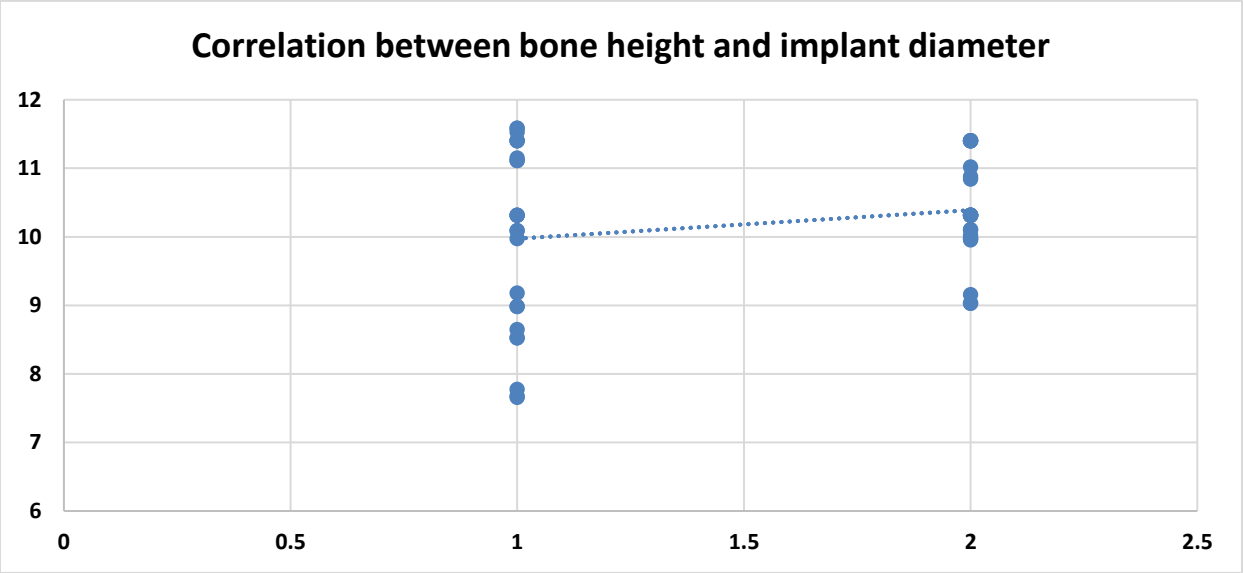

Figure (6): Scattered chart representing correlation between bone height and implant diameter

This was in accordance with a study performed by Hurley et al.[19] who claimed that the implant forces are lower with a greater AP spread value since it provides better tripodization and a more favorable implant distribution. Shackleton et al.'s study evaluated two cantilever lengths (≤ 15 mm and > 15 mm) for fixed prostheses on implants and agreed with the findings of our study where he reported that short cantilevers had better clinical performance than long cantilevers[11]. A number of studies in the literature concluded that the incorporation of the cantilevers in implant supported prosthesis will increase the magnitude of forces on the crestal bone around the implants, and this overload is proportional to the length of the cantilever and in turn the amount of crestal bone loss [5,6,9,10,12].

The results of this study also revealed a positive (+), weak ($r<0.5$), insignificant ($P<0.05$) correlation between bone height and different implant diameters which was in accordance with multiple studies performed by **Flanagan [20] and Jackson [21]** who reported that small diameter, or mini, dental implants have been successfully used to support removable and fixed oral prostheses**.** According to a study performed by **Al-Nawas et al. [22]** results showed that survival and success rates were 97.8% and 97.6% respectively after 1 year: and 97.6% and 97.4% respectively after 2 years using narrow diameter (Ø 3.3 mm) TiZr alloy implants for 2 years.

CONCLUSION

Both the standard and small implant diameter with different cantilever length showed marginal bone height changes within the physiologic limit for implant supported maxillary prosthesis.

CONFLICT OF INTEREST

There is no conflict of interest, and the study was totally funded by the authors.

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