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ASSESSMENT OF THE CORRELATION BETWEEN IMPLANT DIAMETERS AND CANTILEVER LENGTHS TO ANTERIOR-POSTERIOR SPREAD RATIO UTILIZING RESONANCE FREQUENCY ANALYSIS (IMPLANT STABILITY QUOTIENT)

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ABSTRACT

Objectives: This study aims to assess the correlation between different implant diameters and different cantilever lengths to anterior-posterior spread on the stability of implants placed in maxillary edentulous ridges.

Materials and methods: In sixteen patients, a total of 96 implants were implanted, over which screw-retained implant-supported maxillary prostheses were constructed. The patients were divided into two groups using sealed envelopes for randomization: Group I received implants with a small diameter of 3.0 mm, while Group II received implants with a standard diameter of 3.7 mm. Patients in each group were further divided into two subgroups, Groups IA, IB, and Groups IIA, and IIB. The cantilevers lengths to anterior-posterior AP implant spread (CL: AP) in Groups IA and IIA was at a ratio of 1:3, whereas in Groups IB and IIB, the CL: AP was performed at a ratio of 1:2. Implant Stability Values were measured at 0, 4, 8, and 24 months after prostheses delivery.

Results: The correlation between Implant Stability ISQ values and different implant diameters was calculated by using Spearman`s correlation coefficient which revealed a positive (+), weak (r=0.21), insignificant (P=0.16) correlation, while the Correlation between Implant Stability ISQ values and different cantilever lengths were calculated by using Spearman`s correlation coefficient which revealed a negative (-), weak (r=-0.529), significant (P<0.0001*) correlation.

Conclusion: Within the limitations of this study, it can be concluded that changing the AP spread to cantilever lengths and varying implant diameter may have an impact on the stability of implants supporting maxillary screw-retained prostheses.

KEYWORDS: edentulous maxillae, small diameter implants, screw retained, Cantilever

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INTRODUCTION

Immediately following teeth extraction, the alveolar ridge begins to resorb by almost 60%, and this process intensifies over the first year [1,2]. Other factors such as trauma, deformity, neoplasms, and periodontal disease can also accelerate the loss in bone width [3]. This presents difficult constraints for implant placement. To increase insufficient bone volume in certain circumstances, surgical augmentation procedures may be required [3]. However, there will always be potential surgical risks including postoperative discomfort, infection, nerve damage, bone fractures, hemorrhage, wound dehiscence, and implant failure. There is a greater need for other treatments because of the higher morbidity, higher expense, and longer recovery and healing times periods required. [3]

Regenerative techniques are also thought to have a high risk of complications in older or medically fragile compromised patients [4,5]. As a result, emerging ideas like narrow-diameter dental implants (NDI) are generating more and more interest in both the clinical and scientific communities. The use of Narrow Diameter Implants has been shown to increase treatment options, prevent more invasive procedures, reduce patient morbidity, and shorten treatment times according to Schiegnitz et al. [4]. Furthermore, González-Valls et al.'s [6] systematic review of small-diameter implants concluded that NDIs are a predictable therapeutic option because they have good survival, success, and acceptable bone loss rates that are equivalent to those of SDIs.

The Glossary of Prosthodontics defines a cantilever as a fixed bridge with a free end that is supported and retained exclusively on one end by one or more abutments [7]. It was proposed that to lessen the stresses transmitted to the implants and the supporting bone, the length of the cantilever should be restricted to the size of two teeth after the last implant in the mandible and to just one tooth in the maxilla [8]. According to several publications, having cantilevers that are too long will make prosthetic failures more likely [7-9].

For fixed implant-supported prostheses, Shackleton et al. [10] investigated two cantilever lengths (15 mm and > 15 mm) and found that short cantilevers performed better clinically than long cantilevers. According to Sertgöz et al. [9], lengthening the cantilever will increase the stress at the implant interface. English [11] suggested that a very reasonable rule of thumb for calculating the posterior cantilever in a mandibular implant-supported prosthesis should be 1.5 times the A-P-spread (roughly 10–12 mm for the mandible), while the posterior cantilever for the maxilla should be reduced to 6–8 mm due to low bone density. Another study stated that to get a general idea of how long a distal cantilever could be appropriate, the AP spread can be doubled by 1.5–2.5%. [12].

The objective of this clinical investigation is to ascertain whether there is a correlation between the variations in cantilever length and implant diameter affecting the stability of implants supporting maxillary prostheses.

MATERIALS AND METHODS

At Cairo University's Faculty of Dentistry, sixteen patients were selected from the Prosthodontics Department's clinic. From within the pool of completely edentulous patients, Candidates were picked based on a strict inclusion criterion that mandated that they had to be systemically and orally free of any medical conditions, have a Class I Angle classification, and have no para-functional habits.

Sample size calculation

After a two years follow-up period, Khorshid et al. [13] evaluated the changes in bone height between two different diameters with various cantilever lengths. Bone height variations were measured to be 1.33± 0.24 mm in subjects receiving screw-retained prostheses with a 1:2 cantilever length utilizing standard implant diameter. Based on expert opinion, a clinically significant difference of 0.4 was used.

7 patients were reported in each group, for a total of 14 patients, using an independent-t test with a power of 80% and 0.05 alpha significance. Eight patients were recruited in each group, for a total of 16 patients, with 10% added to account for dropouts.

In sixteen patients, a total of 96 implants were inserted, over which screw-retained implant-supported maxillary restorations were manufactured. Using sealed envelopes, the patients were randomly divided into two groups: Group I received implants with a small diameter of 3.0 mm, while Group II received implants with a standard diameter of 3.7 mm. Patients in each group were once again randomly and blindly split to obtain a total of four subgroups, Groups IA, IB, IIA, and lastly IIB. The anterior-posterior AP implant spread to the cantilevers lengths (CL: AP) in Groups IA and IIA was made at a ratio of 1:3, whereas in Groups IB and IIB, the AP spread to the cantilevers lengths (CL: AP) was made at a ratio of 1:2.

All participants who were enrolled in this trial received conventional complete dentures. To create radio-opaque scan appliances, the maxillary dentures were duplicated using a blend of translucent self-cured acrylic resin powder and amalgam powder. All patients underwent a Cone Beam Computed Tomography (CBCT) (Scanora 3D Soredex, Helsinki, Finland) while placing the radiographic scan appliance intraorally and secured them in position by biting on an occlusal index, separating the mandibular teeth from the stent. The Mimics program (Mimics, Materialise HQ, Technologielaan 15, 3001 Leuven, Belgium) was used to obtain coronal and sagittal reformatting as well as panoramic views after the DICOM files from the CT scan were loaded into the software. The radiolucent channels that were previously made in the radiographic scan appliance in the midline of each tooth were used to identify the appropriate implant locations. It was assessed using measuring tools in the software whether the bone at each of the six prospective locations had enough height, width, and density of bone.

Six implants were to be designed in the lateral incisor/Canine region, first premolar region, and first molar region. The four anterior implants had a standard height of 13 mm, while the two posterior implants had a standard height of 10 mm. The Mimics software was used to import the virtual STL files of the implants, and virtual planning was then carried out at the suggested implant sites using the Mimics software.

The segmentation procedure was used to separate the bone and teeth from the base of the radiography stent. Using the "Boolean operation" tool, the produced mask of the base was expanded into a 3D object and then joined with the upper bony component of the implant model. The finished 3D virtual stent was exported as an STL (Sterolithiographic) file for 3D printing using an Invision Si2 (USA) machine. The produced stent's intended holes were fitted with metallic sleeves. After that, the surgical stent was placed in the patient's mouth to test its retention and stability.

Implant Installation

Before beginning surgical implant installation, the patient's peri-oral area was cleaned with an antiseptic solution containing betadine, and the computer-guided stent was cleaned with an appropriate disinfectant. Three fixation screws were used to secure the surgical guide. Following that, osteotomies were produced using the traditional drilling sequence (pilot, intermediate, and final drills), and each drill was followed by sterile saline irrigation as shown in Figure 1A. A "drill guide," which was particularly manufactured for each drill size, was used for each drill. The implants were manually placed through the stent before being further tightened with a ratchet and an implant driver with depth control. The computer guided surgical stent was the retrieved as shown in Figure 1B and using the "Osstell" ISQ equipment (Osstell AB, Gamlestadsvägen 3B, SE415 02, Sweden), each implant's primary stability was evaluated. Using a soft liner, the patients' dentures were relined and the implants were left for 4-6 months to allow the healing of the implants.

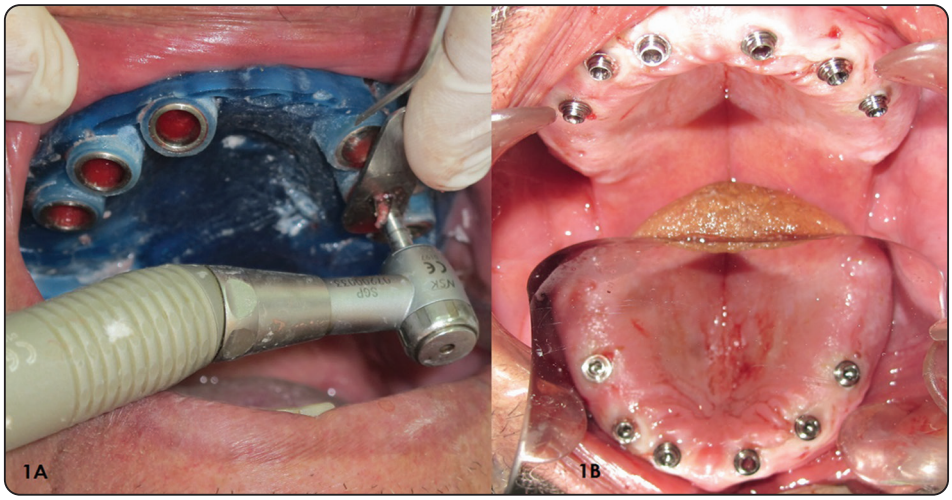

Fig. (1) 1A: Osteotomy performed using the classical drilling sequence (pilot, intermediate and final drills) 1B: Implants after being surgically installed and stent retrieval

Within 4-6 months, the patients were recalled, and the Osstell device was used to record the implant stability (ISQ). Preliminary impressions were then obtained utilizing a closed tray technique and medium body rubber base impression material. Following the placement of the implant analogs (Implant Direct TM LLC Spectra-System Dental Implants, Calabasas Hills, CA, USA) on the plastic transfer copings inside the impression, medium hard stone was used to pour the impression.

The implant analogs in the primary cast were then fastened with temporary titanium abutments, and a verification jig was built using DuraLay resin (DuraLay TM, Reliance, Dental MFG Co. Worth, IL, USA). After that, the verification jig was screwed over the implants intraorally to check for passivity using an intraoral explorer and the one-screw test. In cases of non-passive areas of the framework, it was sectioned as shown in Figure 2A and then re-connected intra-orally again using Dura lay. After the complete set of the DuraLay, the passive fit was then checked finally.

The radiographic stents were then modified to be used as a special tray to perform an open tray impression technique. Plastic abutments (Plastic burnouts, ImplantDirectTM LLC Spectra-System Dental Implants Calabasas Hills CA, USA) were fixed firmly to the implant analogs in the master cast as shown in Figure 2B which were connected with Duralay resin and waxed up to create the framework pattern. In this study, two straight rulers, one placed across the center of the bilateral anterior implants' screw access holes and the second across the center of the bilateral posterior implants' screw access holes, were used to measure the anterior-posterior spread for each of the 16 cases included. The exact AP Spread was then determined by measuring the distance in millimetres between these two straight anterior and posterior lines using a Boley gauge as shown in Figure 2B. Each case's cantilever segment length was created during the waxing-up step based on the initial grouping they were assigned to, i.e., Group A or B, and the AP spread measurement that was recorded for each patient. Investment, wax elimination then casting into chrome cobalt alloy were then completely.

The Wax wafer registration method was then used to register the bite. Following Misch's [16] recommendations, the setting of acrylic teeth was performed following the Implant Protected concept of Occlusion. The gingiva was then built by utilizing the Visiolign Veneering (Visiolign, Bredent GmbH & Co.KG, WeissenhornerSenden, Germany) light-cured technology as shown in Figure 3A and B.

After the build-up was finished, the screw-retained implant-supported prostheses were

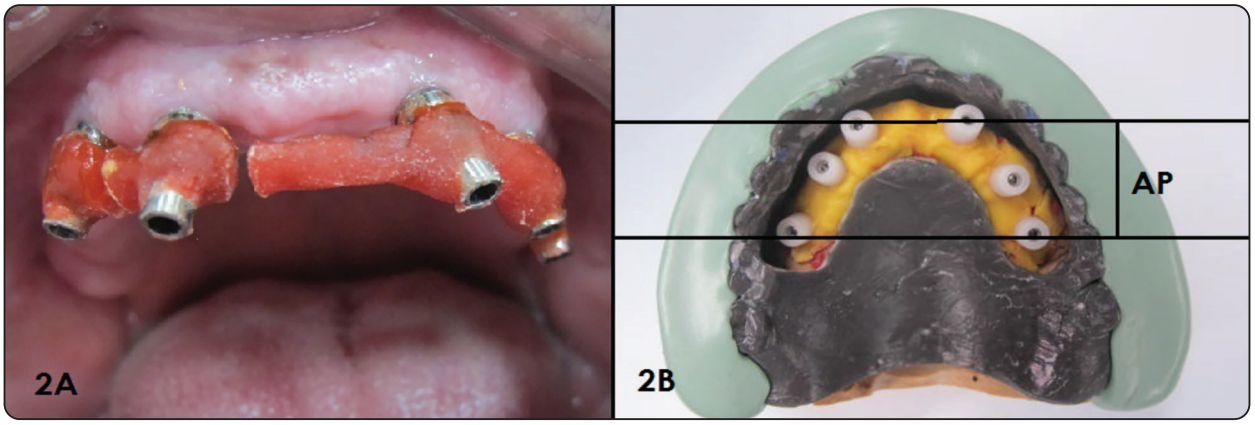

Fig. (2) A: Verification jig checked for Passivity intra-orally and sectioned in areas of non-passivity. B: Plastic abutments fixed firmly to the implant analogs in the master cast and AP Spread for each case being measured.

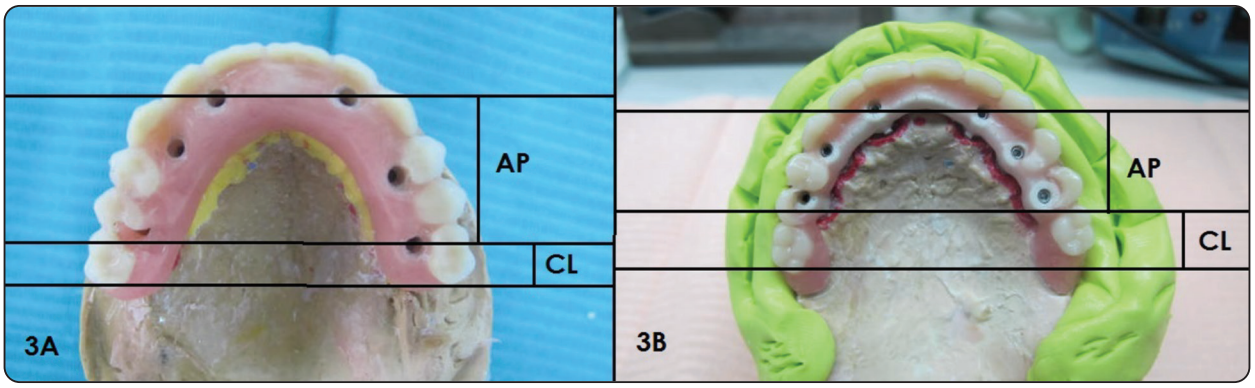

Fig. (3) A: Restoration fabricated on the cast with CL=Cantilever Length to AP=Antero-posterior Spread ratio of 1:3. B: Restoration fabricated on the cast with CL=Cantilever Length to AP=Antero-posterior Spread ratio of 1:2.

checked on the master cast and intra-orally to check for passivity using the one-screw test. The presence of any gap indicates the need for sectioning, re-connection using Duralay, and soldering (or welding). Fine occlusal adjustments were performed followed by tightening of the prosthetic screws to 30Ncm using a torque wrench. Rubber pieces were used to partially seal the access holes, and light-cured composite resin restorative material was used to restore full occlusal contact with the mandibular teeth Figure 4a and B.

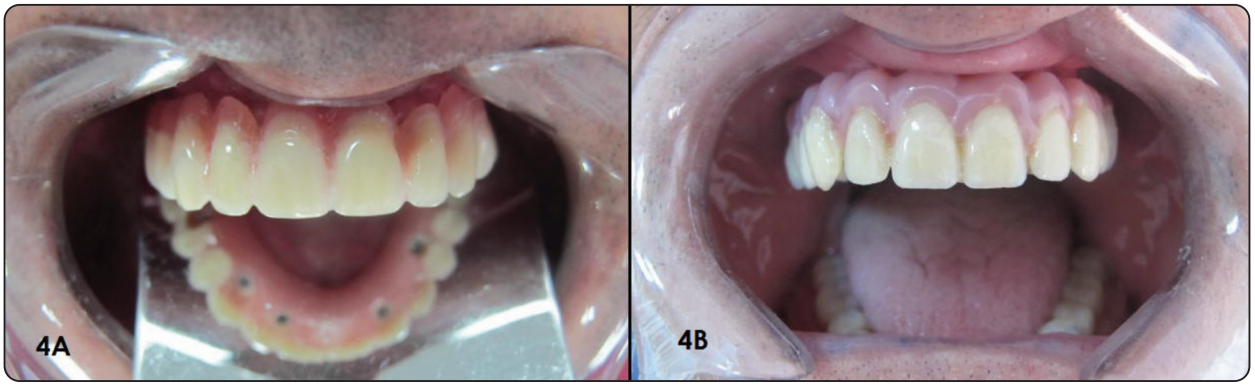

Fig. (4) A: The screw-retained implant-supported prostheses delivered to the patient's mouth A: Group I. B: Group II.

Follow-up and Statistical Methods

In this clinical investigation, each patient performed four follow-up visits. Osstell Values were measured buccally, palatally, mesially, and distally surrounding each of the 6 implants for each patient involved in this study to evaluate the hard tissue reactions in all groups at zero, four, eight, and twenty-four months after definitive prostheses delivery as shown in Figure 5. The numbers obtained were then tabulated and statistically analyzed.

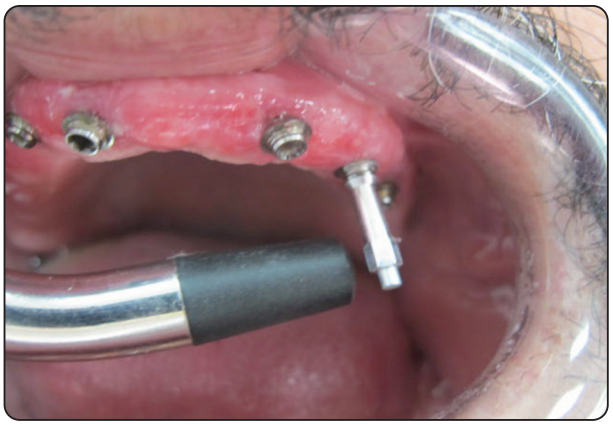

Fig. (5) Lingual Bone Implant Stability measurements using the Osstell Device.

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. The correlation between bone stability values and different implant diameters was 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 findings of this study were statistically analyzed to determine the changes that took place in the hard tissue supporting structures of the maxillary implants as a result of utilizing two different implant diameters with two different Cantilever lengths. Resonance Frequency Analysis Values collected utilizing the Osstell system to test the Implant Stability were used in this study to measure changes in the hard tissue implant supporting structures. At zero, four, eight, and twenty-four months after definitive prostheses delivery, Osstell Values were assessed buccally, palatally, mesially, and distally around each of the 6 implants in all groups.

TABLE (1) Mean and standard deviation of Osstell values primary stability results in all groups at different intervals:

Osstell		Group I		Group II		P value
		M	SD	M	SD	
	A	67.06	0.39	63.53	3.56	0.09
Baseline	B	62.21	2.78	66.99	0.16	0.01*
	P value	0.01*		0.1		
	A	64.22	2.25	60.71	1.79	0.06
After 4 months	B	55.86	1.58	60.70	3.67	0.04*
	P value	0.0009*		0.99		
	A	57.75	3.36	62.38	3.32	0.09
After 8 months	B	53.65	0.89	57.26	2.81	0.04*
	P value	<0.0001*		0.058		
	A	57.68	3.21	62.68	4.20	0.1
After 24 months	B	52.36	0.93	56.44	3.10	0.04*
	P value	<0.0001*		0.54		

M: mean ***SD: standard deviation*** ****Significant difference as P<0.05***

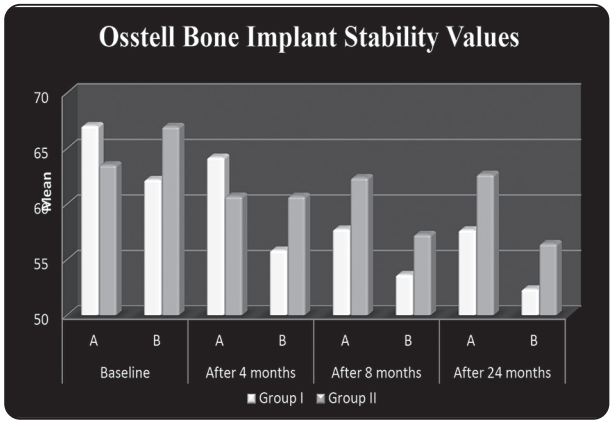

Fig. (6) Bar chart showing Osstell values primary stability results in all groups at different intervals.

The mean values (m) and standard deviation (St.D) of the Resonance Frequency analysis Osstell Values in all Groups were shown in Table 1 and Figure 6. Correlation between Implant Stability ISQ values and different implant diameters was calculated by using Spearman`s correlation coefficient which revealed a positive (+), weak (r=0.21), insignificant (P=0.16) correlation, as presented in Table 2 and Figure 7.

Additionally, the Correlation between Implant Stability ISQ values and different cantilever lengths was calculated by using Spearman`s correlation coefficient which revealed a negative (-), weak (r=-0.529), significant (P<0.0001*) correlation, as presented in Table 2 and Figure 8.

TABLE (2) Spearman's correlation coefficient between Implant Stability and implant length and between Implant Stability and cantilever length:

Correlation	r	P	Indication
Implant diameter and Implant Stability	0.21	0.16	Weak / positive /insignificant
Cantilever length and Implant Stability	-0.529	<0.0001*	Moderate / Negative /Significant

r: Spearman's correlation coefficient

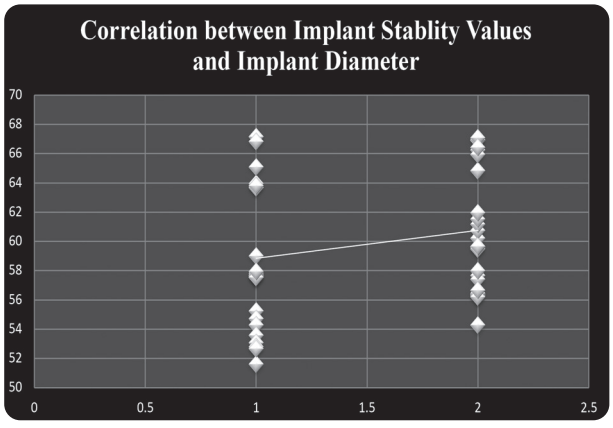

Fig. (7) Scattered chart representing correlation between implant stability and implant diameter

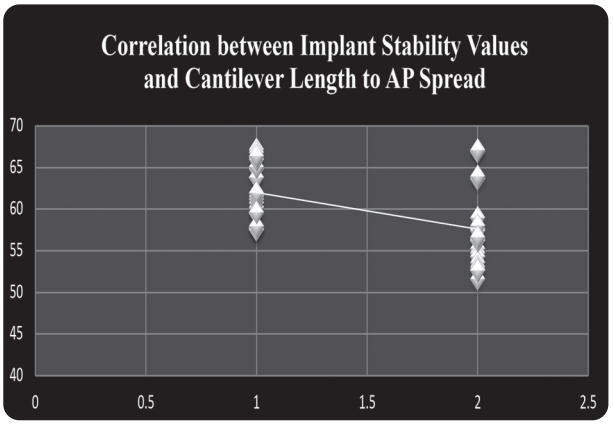

Fig. (8) Scattered chart representing correlation between implant stability and cantilever length

DISCUSSION

According to the 2008 Pisa Consensus Conference of the ICOI (International Congress of Oral Implantologists), all implants in this study were declared to have successfully osseointegrated [14]. The majority of the study participants were content with their implant-supported restorations since they transitioned from a removable complete denture to a fixed screw-retained restoration, which offered superior masticatory performance, more comfort, and the elimination of the flanges.

This study measured the implant stability quotient in both groups using resonance frequency analysis with the Osstell device to determine if there was any relationship between the implant stability and various implant widths and AP: CL Ratios. Meredith [15] and Friberg et al. [16] also proposed the hypothesis that the definition of an implant stability quotient value (ISQ) is pertinent to predicting the prognosis of osseointegration of implants. As stated by Gedrange et al. [17], the resonance frequency analysis is related to the implant's stiffness in the surrounding bone tissues. Stiffness in viable bone is time-dependent because, as noted by Abrahmsson et al. [18], the osseointegration healing process causes the bone to grow and remodel in the direction of the implant surface.

Each maxilla received six implants to ensure that there would be enough implants to hold maxillary prostheses with longer cantilever lengths. The most distal implant was also placed in the molar region. This was consistent with a study by McAlarney and Stavropoulos [19] who found that the ability to cantilever was also influenced by the number of implants since these results in a more even distribution of implant force. They also added that the more distal the most posterior implant, and the more mesial the most anterior implant, the wider the AP spread and hence the more permissible it is to do more Cantilever Lengths In accordance with Drago's study [20], the A/P spreads and CLs were measured in this investigation using a millimeter ruler and a Boley gauge.

The findings of this study which revealed a positive, weak, insignificant correlation between Implant Stability ISQ values and different implant diameters confirmed those of numerous studies[21,22] that claimed small diameter or mini, dental implants have been successfully used to support both removable and fixed oral prostheses. Misch [23] agreed that increasing implant width becomes more significant than increasing implant length since every 0.25 mm increase in width results in an increase in total surface area of 20–30%, which reduces loads at the crestal bone–implant contact.

According to a study by Hurley et al. [21], higher AP spread values result in lower implant forces because they improve tripodization and result in a more advantageous implant distribution which supported the results of the current study. Additionally, and in agreement with the findings of our investigation, Shackleton et al. 's study [10] examined two cantilever lengths (15 mm and > 15 mm) for fixed prostheses on implants. He reported that small cantilevers performed better clinically than long cantilevers [10]. Numerous studies found that the addition of cantilevers to implant-supported prostheses increased the magnitude of force applied to the crestal bone surrounding the implants. This overload was proportional to the length of the cantilever, which in turn increased the amount of forces directed to the crestal bone around the implants [9-12].

CONCLUSION

Within the limitations of this study, it can be concluded that changing the AP spread to cantilever lengths and reducing the implant diameter may have a negative impact on the stability of the implant-supporting maxillary screw-retained prosthesis.

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