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Effect of Diameter and Length and the Influence of Position of Dental Implant on the Distribution of Occlusal Stress on the Success Rate of Dental Implant

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Abstract Replacing missing teeth by dental implant is one option used nowadays. It is important to estimate the success rate of this treatment and to consider main variable that influence the success rate of this treatment. Among these factors to be considered is Length and diameter of dental implant supplied by many manufacturer company. The position of dental implant in oral cavity and the nature and magnitude of the applied force during mastication and parafunctional habits are other factors to be consider during treatment. **Objectives:** The influence of diameter, length and position of dental implant on success rate of dental implant treatment. **Materials and Method:** Prospective study involve (697) patients. Age (18-77y) and involve male (387), female (310). The study was done in department of dental implantology in Al-Ramadi health center. The study was done between (2013-2017). The criteria used for assessment patient prior to implant surgery as follow: The patients with no systemic disease, good glycemic control, good oral hygiene, no periodontitis, abstain tobacco 2 weeks before surgery. 820 easy implant® by franch dental implants manufacturer with sandblast surface, cylindrical-conical with internal hexagon and morse taper connection are used to replace teeth. A variety of dental implant length and diameter is used as follow: Upper Central incisor 5×11.5, upper lateral incisors 5×8.5, upper canine 5×8.5, upper 1st premolar 4.3×11, upper 2nd premolar 4.3-8, upper molars 5×7.Lower central incisors 3.5×10, Lower lateral incisor 3.5×10.5, lower canine 3.5×11.5, lower 1st premolar 3.5×8, lower 2nd premolar 3.4×8, lower molars 4.5×7. The patients were followed during the study period clinically and radiographically. The success rate is recorded and compared. **Results:** The statistical analysis of the study in Table 2 & Figure 2, Figure 3 indicate that the higher survival rate was (75.0000 +/- 5.0000) in the AMX 3 area. The lower survival rate was (55.3333 +/- 5.05757) in PM 3 because of short and nonstandardized diameter of dental implant. There is significant difference in mean of survival rate at 0.05 level. **Conclusion:** The diameter, length and position of dental implant are among these factors that should be considered when we estimate the success rate of dental implant treatment.

Keywords: *dental implant, diameter, length, position, occlusal stress*

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1. Introduction

Dental implant stability and retention is important for successful results. It depend on implant design, surface texture, surgical procedure and also on bone quality. [1] Studies suggest that for optimal stability of dental implant diameter more than 4mm and implant length at least 10-14mm (Horiuchi et al & Chiapasco et al). These factors should be discussed in reviews by many studies due to high failure rate related to posterior mandible area due to poor bone quality. [2] The cortical bone decrease in thickness but trabecular bone increase posteriorly. In elderly the type bone classified as IV bone which characterized by thin cortical layer surrounding less strong cancellous bone. Dental implant stability is depend on the thickness of bone cortex. The mastication is strongly dependent on the posterior area So tooth loss mainly occur in this area. [3] Studies nowadays indicate this also not related to special type or system of dental implant. The ridge augmentation techniques with bone graft allow implant to be placed in area with sever resorption. In these area where short and narrow implant play a role which finally affect implant stability and retention. Studies indicate that treatment of resorbed ridges with bone graft or with short dental implant give similar results. But less expensive and fast treatment and less morbidity of short dental implant use make it better choice than advanced ridge augmentation procedures Das Neves et al [4] Studies by Hagi et al indicate that short dental implant with 6-7 mm, with press –fit shape and a sintered porous surface geometry provide good results. [5,6] Studies by Renourad and Nisand concluded high failure rate related with use of short and wide diameter implant in fully and partial edentulous ridge. [7] Telleman et al indicate in his study

on the lower success rate related to short dental implant due to many reasons the less bone to implant contact related to short dental implant, second short implant are placed posterior areas where the bone quality is poor and the sever bone resorption in posterior areas and failure of short implant is due to high ratio of crown to implant. [8] Dental implant diameter 3-7mm is favorable for optimal stress distribution of force in bone around dental implant. And allows maximal amount of bone to engage the implant than narrow diameter. [9] Wide diameter implant is placed for high torque on prosthetic structures. However it is limited by the width of bone ridge and esthetic need. The advantages in use of wide diameter implant is provide more bicortical bone contact and direct placement in failure sites and less stress placed on implant abutment. Thus it provide additional retention and minimal stress and improved resistance to fracture provide by implant with wide diameter. [10] It is necessary in posterior area of mandible with poor bone quality to consider implant length and diameter. Diameter is the width of widest thread of dental implant. Dental implant diameter is more important than length in distribution of load in around bone. At least 3.25 implant width is need to ensure optimal strength. [11] FEA used in dentistry as useful method to estimate the distribution of stress on dental implant and around bone. [12,13] Mastication induce vertical and transverse force and bending force that cause load gradient over the implant and bone. [14] The highest natural force applied up on tooth or dental implant during mastication 42 Ib. This force increase to 1000 Ib during parafunction. [15] Heavy occlusal load on dental implant lead mechanical complications to the prosthetic appliance like screw loosening and fracture, abutment fracture and also implant fracture. Signs of occlusal load increase on dental implant include; Inflammation and crater-like bone defects with increase in width of PDL, fremitus and mobility of tooth. [16] In vivo studies compare and quantified the load applied to dental implants and teeth under various physiological occlusal functions. The results indicate equal load level applied on dental implant and teeth. Control factors which transmit force to dental implant is mandatory. Contraversy exist on the relation between peri-implantitis and applied occlusal load which consequently lead to implant failure. [17] Loss of ossteointegration and crater like bone defects caused by axial and lateral occlusal load. This loss of ossteointegration produced also due to use of short and narrow implants, high occlusion, or sever lateral over force. Also use implant with smooth surface instead of rough which have better survival rate. [18] For implant to success bone with adequate quality and good stress distribution are main factors. Implant place in bone with thick cortical bone and dense trabecular core result in less micro-movement and less stress concentrated which stabilize dental implant and integrate well. [19] FEA indicate that maximum von Mises stress decrease with thick cortical bone, but it decease as the cortical bone modulus of elasticity increases. [20] Marginal bone loss is greater around short dental implant which used in situation of short bone height like in case of pneumatization of maxillary sinus and proximity of inferior dental canal. Failure rate in short dental implant is higher in comparison with long on (85%) [21,22].

2. Materials and Method

Prospective study involve (697) patients. Age (18-77 y) and involve male (387), female (310). The study was done in Al-Ramadi health center in department of dental implantology. The study was done between (2013-2107). The criteria used for assessment patient prior to implant surgery as follow: No systemic disease (heart disease), good glycemic control, good oral hygiene, no periodontitis, the bone quality and tissue thickness is good, no smoking 2 week before surgery, the patient should complaint regarding dental implant surgery with good economic level. 820 easy implant® by franch dental implants manufacturer with sandblast surface, cylindrical-conical with internal hexagon and Morse taper connection are used. The patients is under go good clinical, radioraphical examination before surgery and dental examination. OPG (Orthopantomograph) is used to measure the location of adjacent vital structures related to dental implant site: Floor of maxillary sinus, floor of nasal cavity and mandibular canal. The patients were treated under local anesthesia (2%xylocaine with1:80000 adrenalin) using flap surgery. Antibiotic cover were prescribed in post-surgical period (Ampicillin 500mg four time per day /week). The dental implants were kept unloaded during healing period. Variety of dental implant length and diameter is used as follow: Upper Central incisor 5×11.5 (n=80), upper lateral incisors 5×8.5(n= 75), upper canine 5×8.5(n=70), upper 1st premolar 4.3×11(n=76), upper 2nd premolar 4.3-8(n=67), upper molars 5×7(n=76). Lower central incisors 3.5×10(n=50), Lower lateral incisor 3.5×10.5(n=67), lower canine 3.5×11.5(n=78), lower 1st premolar 3.5×8(n=55), lower 2nd premolar 3.4×8(n=50), lower molars 4.5×7(n=76). The patients were followed during the study period clinically and radio graphically 2,6and 12 months after dental implant surgery. The criteria assessment the success of dental implant is used: No pain, no mobility, no suppuration and inflammation with no peri-implant radiolucency. Dental implant success rate were recorded and compared.

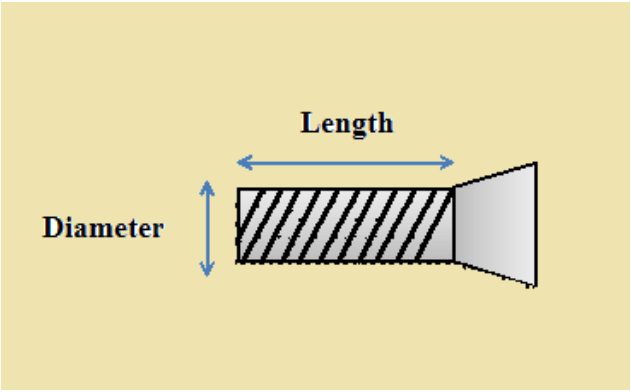

Figure 1. The Length and diameter of dental implant

3. Statistical Results

The statistical analysis of the study Table 2 & Figure 2, Figure 3 demonstrate the effect of length and diameter & position of dental implant on the success rate of dental

implant for (697) patients come to replace their teeth. The results indicate that the highest survival rate was (75.0000 +/- 5.0000) in AMX 3 position. While the lowest survival rate in PM 3 was (55.3333 +/- 5.05757). The survival rate AM3 is (66.3333 +/- 5.13160) & PMX3 is (62.6667 +/- 12.50333). The mean difference is significant at 0.05 level.

The results in Table 5 and Figure 4 of our study indicate that the highest mean of failure was in PM3 (12.2667 +/- 6. 75599). While AMX3 show the lowest mean of failure near (0.0000+/-0.00000). The mean of failure in AM3 was (4.7367 +/- 1.05557) and in PMX3 was (5.6000+/- 1.12694). The mean difference is significant at 0.05 level.

Table 1. Chi-square tests show statistical significant difference between different treated positions

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	7.333[a]	7	.395
Likelihood Ratio	10.044	7	.186
N of Valid Cases	12		

a. 16 cells (100.0%) have expected count less than 5. The minimum expected count is. 50.

Table 2. Show mean survival rate of different treated positions

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	A MX 3	75.0000	5.00000	2.88675	62.5793	87.4207	70.00	80.00
2.00	P MX 3	62.6667	12.50333	2.96273	53.5857	79.0809	50.00	75.00
3.00	A M 3	66.3333	5.13160	7.21880	31.6067	93.7267	62.00	72.00
4.00	P M 3	55.3333	5.50757	3.17980	41.6518	69.0149	50.00	61.00
Total	12	64.8333	9.89796	2.85730	58.5445	71.1222	50.00	80.00

Table 3. Anova- test of analysis of variance of different treated positions in mean of survival

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	601.667	3	200.556	3.371	.075
Within Groups	476.000	8	59.500		
Total	1077.667	11			

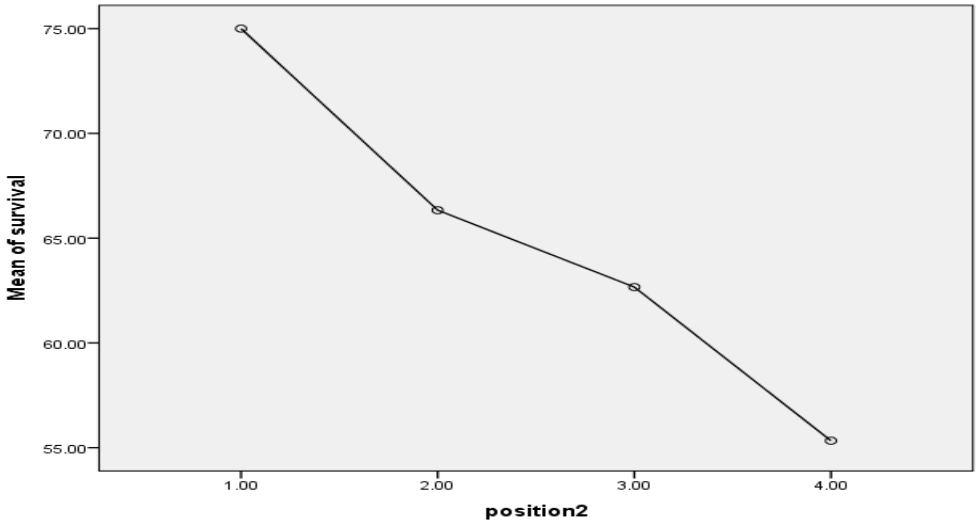

Figure 2. The relation of dental implant positions and mean of survival

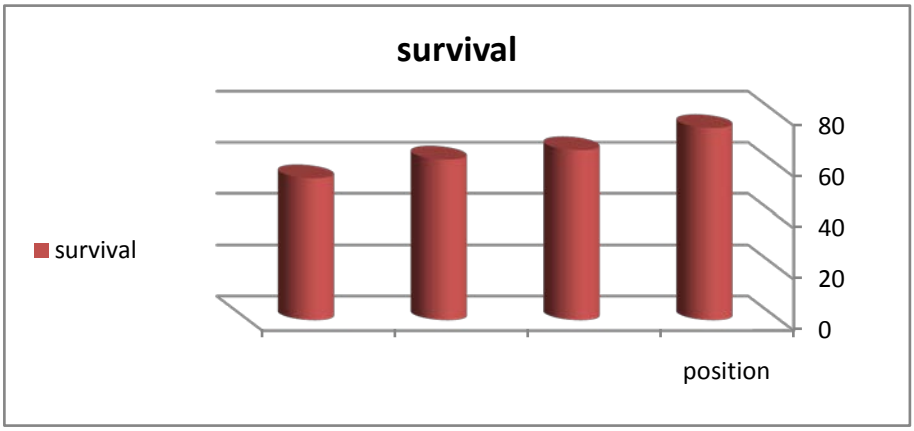

Figure 3. The relation between different treated positions in mean of survival

Table 4. Show multiple comparison of different treated positions in the mean survival rate

(I) position2	(J) position2	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	8.66667	6.29815	.206	-5.8569-	23.1902
	3.00	12.33333	6.29815	.086	-2.1902-	26.8569
	4.00	19.66667*	6.29815	.014	5.1431	34.1902
2.00	1.00	-8.66667-	6.29815	.206	-23.1902-	5.8569
	3.00	3.66667	6.29815	.576	-10.8569-	18.1902
	4.00	11.00000	6.29815	.119	-3.5236-	25.5236
3.00	1.00	-12.33333-	6.29815	.086	-26.8569-	2.1902
	2.00	-3.66667-	6.29815	.576	-18.1902-	10.8569
	4.00	7.33333	6.29815	.278	-7.1902-	21.8569
4.00	1.00	-19.66667-*	6.29815	.014	-34.1902-	-5.1431-
	2.00	-11.00000-	6.29815	.119	-25.5236-	3.5236
	3.00	-7.33333-	6.29815	.278	-21.8569-	7.1902

*. The mean difference is significant at the 0.05 level.

Table 5. Show failure % of different treated positions

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	3	.0000	.00000	.00000	.0000	.0000	.00	.00
2.00	3	5.6000	1.12694	.65064	2.8005	8.3995	4.90	6.90
3.00	3	4.7367	1.05557	.60944	2.1145	7.3589	3.84	5.90
4.00	3	12.2667	6.75599	3.90057	-4.5161-	29.0495	6.50	19.70
Total	12	5.6508	5.44120	1.57074	2.1937	9.1080	.00	19.70

Table 6. Anova –test of analysis of variance of different treated positions in mean of failure

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	229.618	3	76.539	6.375	.016
Within Groups	96.055	8	12.007		
Total	325.673	11			

Table 7. Show multiple comparison of different treated positions in the mean failure

(I) position2	(J) position2	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	-5.60000-	2.82924	.083	-12.1242-	.9242
	3.00	-4.73667-	2.82924	.133	-11.2609-	1.7876
	4.00	-12.26667-*	2.82924	.002	-18.7909-	-5.7424-
2.00	1.00	5.60000	2.82924	.083	-.9242-	12.1242
	3.00	.86333	2.82924	.768	-5.6609-	7.3876
	4.00	-6.66667-*	2.82924	.046	-13.1909-	-.1424-
3.00	1.00	4.73667	2.82924	.133	-1.7876-	11.2609
	2.00	-.86333-	2.82924	.768	-7.3876-	5.6609
	4.00	-7.53000-*	2.82924	.029	-14.0542-	-1.0058-
4.00	1.00	12.26667*	2.82924	.002	5.7424	18.7909
	2.00	6.66667*	2.82924	.046	.1424	13.1909
	3.00	7.53000*	2.82924	.029	1.0058	14.0542

*. The mean difference is significant at the 0.05 level.

Table 8. The mean of diameter of dental implant in different positions

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	3	5.0000	.00000	.00000	5.0000	5.0000	5.00	5.00
2.00	3	4.5333	.40415	.23333	3.5294	5.5373	4.30	5.00
3.00	3	3.5000	.00000	.00000	3.5000	3.5000	3.50	3.50
4.00	3	3.8333	.57735	.33333	2.3991	5.2676	3.50	4.50
Total	12	4.2167	.68202	.19688	3.7833	4.6500	3.50	5.00

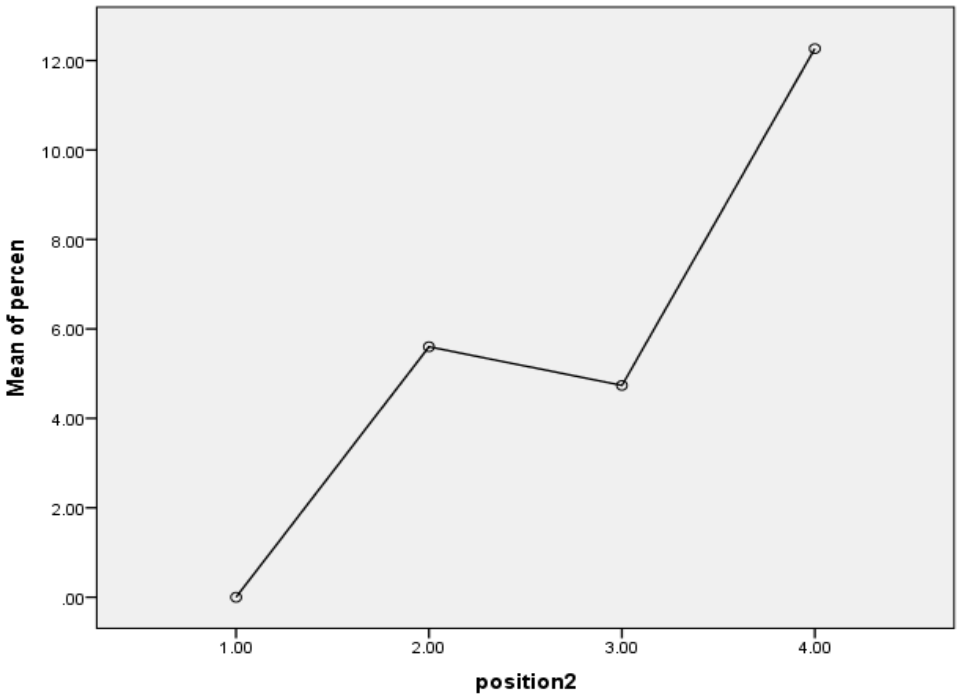

Figure 4. Show relation between positions and mean of failure percent

Table 9. Anova-test of analysis of variance between different positions in mean of diameter

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.123	3	1.374	11.069	.003
Within Groups	.993	8	.124		
Total	5.117	11			

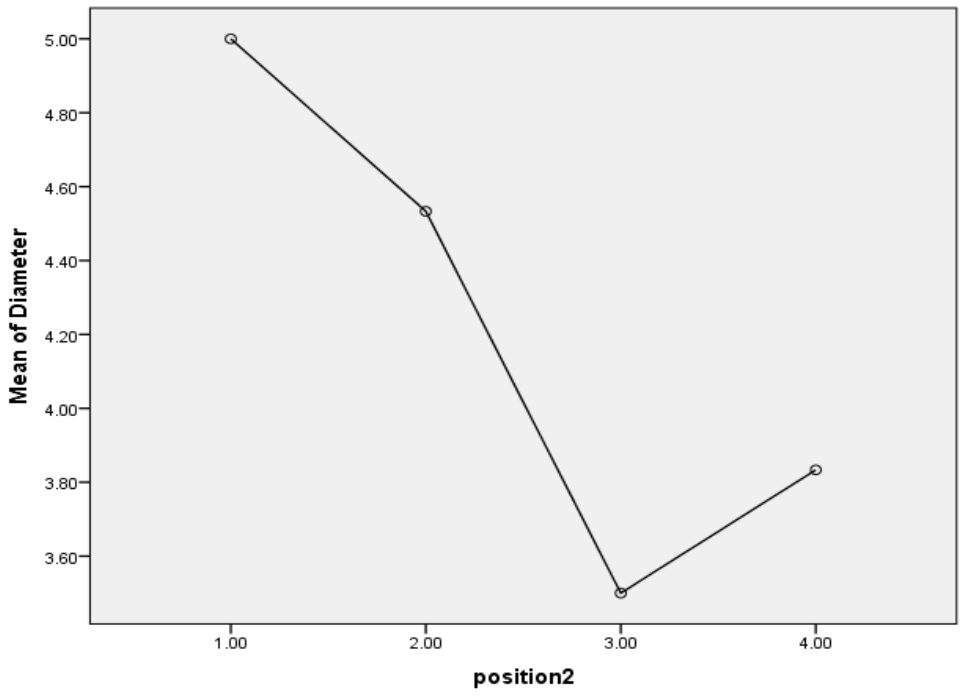

Figure 5. The relation between mean of diameter of dental implant and different positions

The statistical analysis of our study Table 8 & Figure 5 show the higher mean of diameter of dental implant was in AMX3 (5.0000 +/- 0.0000). While lower mean of diameter in AM3 (3.5000 +/- 0.00000). The mean of diameter in PM3 was (3.8333 +/-0.57735) and in PMX3 was (4.5333 +/- 0.40415). The mean difference is significant 0.05 level.

The results of our study in Table 11 & Figure 6 show the highest mean of length of dental implant was in AM3 (10.6667 +/- 0.76376). While the lower mean of length in PM3 is (7.6667 +/- 0.57735). The mean of length in AMX3 was (9.5000 +/- 1.73205) and in PMX3 (8.6667 +/- 2.08167). The mean difference is significant at 0.05 level.

Table 10. Show multiple comparison in mean diameter between different positions

(I) position2	(J) position2	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.46667	.28771	.143	-.1968-	1.1301
	3.00	1.50000*	.28771	.001	.8365	2.1635
	4.00	1.16667*	.28771	.004	.5032	1.8301
2.00	1.00	-.46667-	.28771	.143	-1.1301-	.1968
	3.00	1.03333*	.28771	.007	.3699	1.6968
	4.00	.70000*	.28771	.041	.0365	1.3635
3.00	1.00	-1.50000-*	.28771	.001	-2.1635-	-.8365-
	2.00	-1.03333-*	.28771	.007	-1.6968-	-.3699-
	4.00	-.33333-	.28771	.280	-.9968-	.3301
4.00	1.00	-1.16667-*	.28771	.004	-1.8301-	-.5032-
	2.00	-.70000-*	.28771	.041	-1.3635-	-.0365-
	3.00	.33333	.28771	.280	-.3301-	.9968

*. The mean difference is significant at the 0.05 level.

Table 11. The mean of length of dental implant between different positions

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1.00	3	9.5000	1.73205	1.00000	5.1973	13.8027	8.50	11.50
2.00	3	8.6667	2.08167	1.20185	3.4955	13.8378	7.00	11.00
3.00	3	10.6667	.76376	.44096	8.7694	12.5640	10.00	11.50
4.00	3	7.6667	.57735	.33333	6.2324	9.1009	7.00	8.00
Total	12	9.1250	1.68044	.48510	8.0573	10.1927	7.00	11.50

Table 12. Anova-test of analysis of variance in mean of length between different positions

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14.563	3	4.854	2.354	.148
Within Groups	16.500	8	2.063		
Total	31.063	11			

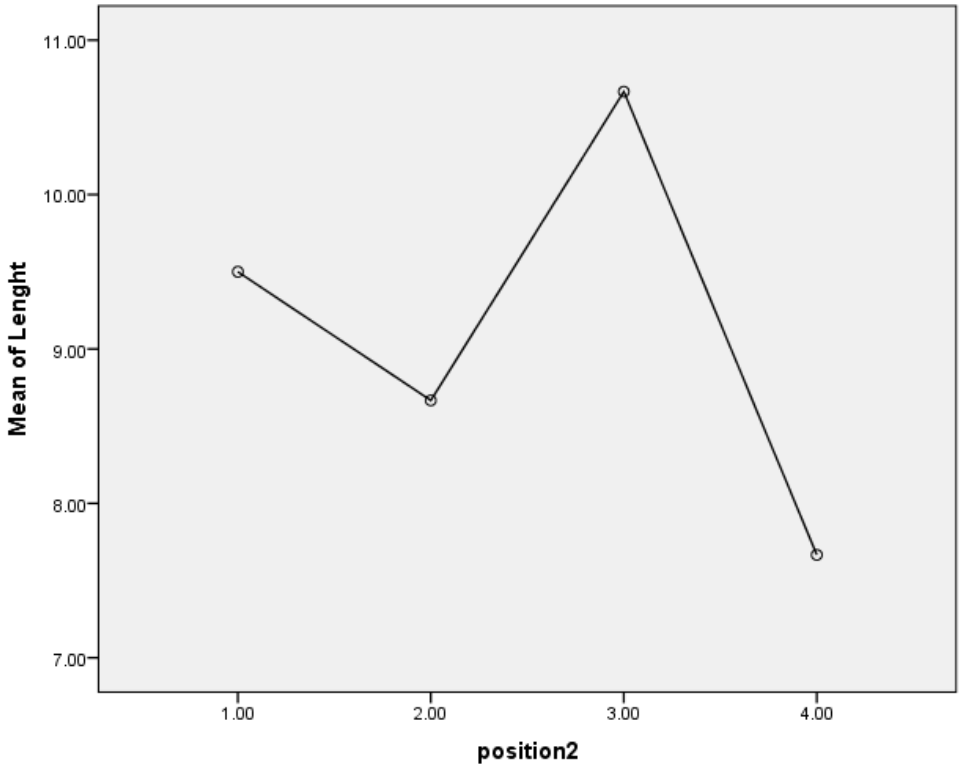

Figure 6. Relation between mean of length of dental implant and position

Table 13. Show multiple comparison between different positions in mean of length

(I) position2	(J) position2	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
1.00	2.00	.83333	1.17260	.497	-1.8707-	3.5374
	3.00	-1.16667-	1.17260	.349	-3.8707-	1.5374
	4.00	1.83333	1.17260	.157	-.8707-	4.5374
2.00	1.00	-.83333-	1.17260	.497	-3.5374-	1.8707
	3.00	-2.00000-	1.17260	.126	-4.7040-	.7040
	4.00	1.00000	1.17260	.419	-1.7040-	3.7040
3.00	1.00	1.16667	1.17260	.349	-1.5374-	3.8707
	2.00	2.00000	1.17260	.126	-.7040-	4.7040
	4.00	3.00000*	1.17260	.034	.2960	5.7040
4.00	1.00	-1.83333-	1.17260	.157	-4.5374-	.8707
	2.00	-1.00000-	1.17260	.419	-3.7040-	1.7040
	3.00	-3.00000-*	1.17260	.034	-5.7040-	-.2960-

*. The mean difference is significant at the 0.05 level.

4. Discussion

One of important areas to be consider is diameter and length of dental implant. Anatomic factors should also to be considered because it required additional treatment before dental implant placement like use of irregular implant. Attempt have been made now the modify the shape of dental implant to optimal level like increase implant diameter and length that increase implant bone contact which reduce stress to the bone when appropriate successful results to be achieved. [25] The results of our study in Table 2 & Figure 2, Figure 3 indicate that the higher mean of survival of implant was in AMX3 (75.0000 +/- 5.0000) because of long and standard diameter dental implants selected. While the lower mean of survival of dental implant was in PM3 (55.3333 +/- 5.55757 due to short and nonstandard diameter of dental implant in area. Rate of survival in AM3 is (66.3333 +/- 5.13160) &PMX3 is (62.6667+/-12.50333). The difference is significant in mean of survival at 0.05 level. Our results is agree with studies conducted by Renouard &Nisand (2006) [26] who indicate that the high failure rate in wide dental implant due to surgical preparation of implant site, weak bone density, poor dentist experience and dental implant design. The short and wide diameter dental implant is indicated in area where the success of dental implant is low due to high bone resportion,old injury and traumatic insults. The failure rate in these area should be compared with that associated with advanced procedures like, ridge rafting, sinus lift procedures and transpositions of mandibular nerve. [27] Peri-implant loss of bone occur due to heavy or wrong occlusal stress along the long axis of dental implant which consequently transmitted to the around bone and affect its health. This load is affected by the type of load, material type of appliance and dental implant, surface feature, geometry and design of dental implant, quantity and type of bone, feature of dental implant contact to bone. [28] Studies (Tarek et al 2015) [18] indicate that Among other factors to be consider when we discuss the cause of failure of dental implant in mandibular molar area related to high occlusal load in these area in comparison with other areas. The mean occlusal load in these area as indicated by FEA is high studies by (Cicciu et al 2014) [29] which results in fracture of dental implant, crowns and even micro fracture of the bone surrounding the dental implant and results in poor retention of dental implant in this area. While in the anterior maxillary area the occlusal load is low in studies by (Alkan et al 2004) [30] which explain the additional factors related to successful dental implant treatment, restorations and good retention of dental implant in theses area. Table 5 & Figure 4 show the failure % in different positions. The highest mean of failure rate in PM3 (12.2667 +/- 6. 75599) due to short and nonstandard diameter of dental implant in this area respectively in comparison with the AM3 area while failure % in AM3 (0.0000+/0.00000) & in AMX3 is (4.7367 +/- 1.05557) due to long and standard diameter of dental implant, the difference is significant in mean failure % at 0.05 level, see also Table 8 & Table 11 show mean of diameter and length of implant in different positions. It has been proved by many studies that the effect of dental implant diameter is more than length in distribution of stress to the surrounding bone. The dental implant diameter should be at least 3.25 for adequate strength but most dental implant are 4mm in diameter. More than this to 7mm diameter are uncommonly used because in sufficient bone available. It has been shown that increase the diameter about 1mm increase the surface area by about 35% for the same length. [31] Dental implant length between 8-13mm which is similar in length to normal root. Success rate increase with increase length but there is no direct relation with implant length and success rate. It is necessary to consider bone quality and quantity, the design of dental implant and surgical technique for successful dental implant treatment. [32] Among other factors that affect this treatment is characteristics of stress and strain, properties of materials, definition of implant surface and the interface of bone to implant. Size of dental implant influence the retention of dental implant; other factors occlusion, force of mastication, dental implant number and position within prosthesis affect forces directed against the bone around dental implant. [33] It is not recommended to use of short dental implant. Because the occlusal stress must be dissipated over a wide implant surface to decrease the stress at bone implant interface [34]. When compare the wide and narrow implant, wide dental implant used when bone is scarce. It allow engagement of maximal amount of bone

and thus distribute occlusal load to a wide surface area. Narrow dental implant with decrease mechanical properties it has more possibility to fracture in overload. The use of wide and short dental implant avoid the mandibular nerve and maxillary sinus floor. In addition of decrease ridge height it avoid the cost augmentation procedure. [35] Analysis the fatigue characteristics of dental implant by FEA. It is an engineering numerical procedure which allow to investigate the stress distribution over dental implant material due to variability of designs, implant length and diameter from mechanical view. [36] The use of variable designs and geometry of endosseous dental implant clinically becoming known today. Dental implant with different diameter, length and shape is introduced widely today. [37] Selection of dental implant depend on the type of edentulous ridge and volume of supporting bone, space available for prosthetic appliance, type of occlusion and emergence profile. The indication of wide diameter implant include: inadequate ridge height, poor bone quality, and immediate replacement of fracture fixture and failure to osseointegrate. [38] Stress and contact of implant to bone also affect the stability of dental implant and therefore the success rate. Wide diameter implant increase the bone implant contact which may compensate the lack of bone height and density. Limitations in bone height is common in posterior maxilla and mandible due to bone resorption from loss of teeth and anatomic limitations from the position of inferior dental canal and floor of maxillary sinus. [39] Increase implant length increase the success rate of dental implant but in literature to a certain extent (13mm). Screw shape 3.3 mm diameter titanium implant has < 25% resistance to fracture which mean increase failure rate, decrease mechanical stability under load in comparison with regular diameter. The use of Short dental implant when insufficient ridge height and its influence on early loss and stability of dental implant [40].

5. Conclusion

Variation in implant design, diameter and length has been proposed overcome the restriction bone anatomy especially in area of posterior maxilla and mandible where the surgical procedures (bone grafting, sinus lift surgery, inferior dental nerve transposition) is indicated than use long and wide dental implant. Minimizing length and /or wide diameter of dental implant is better than surgery. result of our indicate that the highest percent of survival of dental implant in the anterior maxillary area with standard diameter and long dental implant. But there is failure rate of dental implant treatment related to nonstandard diameter and short dental implant in posterior mandible related to poor bone anatomy.

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