ORIGINAL ARTICLE

The effect of implant characteristics on the implant stability of immediately loaded single implant cases: A prospective study

Kolawole O Obagbemiro, Yetunde O Ajayi[1], Patricia A Akeredolu[1], John Ademola Adeoye[2], Godwin T Arotiba[3]

ABSTRACT

Introduction: Factors that affect primary and ultimate implant stability include characteristics of the type of dental implant used, bone quality at the site of implant placement, insertion torque, as well as micromotions at the bone–implant interface. This study, however, sought out to determine the effect and relationship between relevant implant characteristics and implant stability in immediately loaded single implant cases using the Periotest® M handheld device.

Aim: To determine the effect of implant characteristics on the ultimate implant stability in immediately loaded single implant cases.

Results: At placement, 33 (94%) of implants had periotest values between −0.8 and 0 at placement. There is a general decrease in the number of patients with periotest values −0.8–0 and those with +1–9 from the initial placement to 6 months after placement. It was further observed that there is a negative correlation between the implant length, diameter, and the mean periotest values although this was not statistically significant.

Conclusion: There is a directly proportional relationship between implant characteristics and implant stability of immediately loaded implants.

KEY WORDS: Implant characteristics, implant stability, immediate loading, prospective study

INTRODUCTION

While implant therapy has experienced numerous advances in implant designs as well as the surgical and restorative techniques, many clinicians have questioned whether or not the nonloaded healing period is still a valid prerequisite for success.[1] Although not applicable to all patients, the concept of immediately loaded dental implant is not novel but extends back to the 1960s, when implant dentistry was still in its relative infancy.[2] Its protocol advocates the loading of the prosthetic superstructure right after the implant has been placed in the bone.[1] Types of immediately loaded dental implant systems can either be of direct loading type or be of early functional loading type.[3,4] In the direct loading type, the superstructure is attached to the implant within 24 h of implant placement, while in the early functional loading type, it is placed within days or weeks of implant

Prosthetic Dentistry Unit, Federal Medical Centre, Abeokuta, Ogun State, Departments of [1]Restorative Dentistry and [3]Oral and Maxillofacial Surgery, Lagos University Teaching Hospital and College of Medicine, University of Lagos, Lagos, [2]State House Medical Centre, Aso Rock, Asokoro, Abuja-Fct, Nigeria

Address for correspondence: Dr. Kolawole O Obagbemiro, Prosthetic Dentistry Unit, Federal Medical Centre, Abeokuta, Ogun State, Nigeria. E-mail: kollydental@yahoo.co.uk

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placement. A fundamental requirement for immediate occlusal loading stability is adequate primary implant stability. Primary implant stability seems to be the most important determining factor on immediate implant loading as an immobile, functionally loaded implant is an essential ingredient to achieve osseointegration.[5] While stability was traditionally achieved through a period of undisturbed healing in conventional methods of implant placement, primary stability is now achieved via a mechanical phenomenon of screw stability and splinting.[6-8] Factors that affect primary and ultimate implant stability include characteristics of the type of dental implant used including implant length, diameter, and design, bone quality at the site of implant placement (monocortical/bicortical), insertion torque, as well as micromotions at the bone–implant interface. This study, however, sought out to determine the effect and relationship between relevant implant characteristics and implant stability in immediately loaded single implant cases.

MATERIALS AND METHODS

This is a longitudinal, nonrandomized clinical study implemented with a sample size of 35 subjects seeking to undergo single implant rehabilitation for missing teeth at a teaching hospital in Lagos, Nigeria. Recruitment of these individuals occurred consecutively within 1 year as they presented to the clinic with only those who met the inclusion criteria involved in the study.

Inclusion criteria

- Patients with short edentulous span in the maxillary or mandibular arches with not more than two missing teeth
- Patients aged 18–60 years
- Patients edentulous for 4 months and above
- Patients with no contraindications related to surgical or prosthetic procedures
- Patients who gave their informed consent
- Patients with normal-to-dense bone quality in the planned implant site determined by clinical inspection, palpation, and periapical radiograph
- Patients with adequate bone volume to support an implant without the need of bone augmentation
- Patient with edentulous site that permits the placement of an implant at least 10 mm in length.

Exclusion criteria

- Patients with active infection in planned implant sites
- Patients with systemic diseases such as uncontrolled diabetes, poorly controlled hypertension, bleeding disorders, and severely compromised immune system
- Patients with a history of bruxism
- Patients with a need for bone augmentation at the intended site
- Patients with pregnancy or mentally unstable
- Patients with poor oral hygiene, smoking, and not ready to quit the habit
- Patients who cannot keep recall appointments
- Patients who are poorly motivated in maintaining good oral hygiene
- Grossly supraerupted opposing tooth that cannot allow implant prosthesis fabrication
- Patients requiring orthodontic tooth movement
- Second and third molars.

Following clinical and radiographic assessment of subjects who met the inclusion criteria, implants were placed by a single implantologist under adequate presurgical and surgical conditions. Implants of length 10, 11, and 13 mm and diameter 3.7, 4.1, and 4.7 mm were used. To ensure primary implant stability, implant screws were tightened with a manual torque wrench to ensure a torque of 40 N-cm for all participants [Figure 1]. Primary implant stability was also assessed using Periotest® M handheld device (Medizintechnik Gulden, Germany) [Figure 2] before loading.

Subjects were recalled for subsequent visits and Periotest® M handheld electronic device was used to check implant stability at 1, 3, 6, and 9 months and 1 year. According to the manufacturer, interpretations of the periotest readings are as shown in Table 1.[9]

RESULTS

A total of 35 subjects were involved in this study comprising 23 females (66.0%) and 12 males (34%) who were within the age range of 21–60 years with a mean age of 43.14 ± 13.08 and median of 45.00 [Table 2]. Majority of subjects were, however, between ages 51 and 60 years. The mean torque of implants used is 45 N-cm. More implants were placed in the maxilla (71.4%) than in the mandible (28.6%). Most of the implants were 10 mm long (71.4%) and 4.1 mm wide (48.6%). Table 3 summarizes the distribution

Table 1: Periotest (R) value ranges interpretations

Category	Periotest value range	Interpretation
I	−8-0	Good osseointegration, the implant is well integrated and can be loaded
II	+1-+9	A clinical examination is required. Loading of the implant might or might not be possible, depending on the implant type and clinical situation
III	+10-+50	Osseointegration is insufficient, the implant cannot be loaded

Figure 1: Manual torque wrench

Figure 2: Periotest M handheld device

of implant length and diameter of the immediately loaded implants. As regards implant stability, at placement, 33 (94%) participants had periotest values between −0.8 and 0 at placement. There is a general decrease in the number of patients with periotest values −0.8–0 and those with +1–9 from the initial placement to 6 months after placement. However, the number of patients with +10 and above increased from zero at the initial placement to 3 after 6 months. The frequency distribution of periotest values is summarized in Table 4.

Relating implant length to implant stability, 11.5 mm long implants had the highest mean periotest value after placement; however, after 1-year follow-up, the longer implants (13 mm) had the highest mean periotest value. No obvious trend was seen in the periotest value for each implant length over the period of follow-up although the lowest mean periotest values were obtained at 3 months [Table 5].

There was a negative correlation between implant length and the mean periotest value with mean periotest score decreasing and implant stability increasing as implant length increasing although this was not statistically significant [Table 6].

As regards the relationship between implant diameter and implant stability, the mean periotest values at placement decrease as the diameter of the implant increases. However, at 1-year follow-up, the smallest diameter implant (3.7 mm) had the lowest mean periotest value [Table 7]. There was a negative correlation between implant diameter and the mean periotest score; however, this was not statistically significant ($P < 0.05$) [Table 8].

There was a significant difference ($P < 0.05$) between the mean periotest score of implants placed in the mandible and the implants placed in the maxilla, with mandibular implant showing better stability [Table 9]. However, there was no statistically significant difference between the mean periotest scores of implants placed in the

Table 2: Sociodemographic characteristics of participants

	Frequency (%)
Age (years)	
21-30	10 (28.6)
31-40	4 (11.4)
41-50	6 (17.1)
51-60	15 (42.9)
Total	35 (100)
Sex	
Female	23 (66)
Male	12 (34)
Total	35 (100)
Marital status	
Single	11 (31)
Married	24 (69)
Total	35 (100)
Ethnicity	
Igbo	9 (25.7)
Yoruba	26 (74.3)
Total	35 (100)

Table 3: Distribution of implant diameter by length of the 35 immediately loaded implants

Implant length (mm)	Implant diameter (mm)			
Maxilla	3.7	4.1	4.7	Total (%)
10.0	7	6	2	15
11.5	0	1	0	1
13.0	0	9	0	9
Total	7	16	2	25 (71.4)
Mandible	3.7	4.1	4.7	Total (%)
10.0	4	1	5	10
11.5	0	0	0	0
13.0	0	0	0	0
Total	4	1	5	10 (28.6)

Total for maxilla and mandible: 35 (100)

Table 4: Frequency of periotest values at placement of implants to 1 year

Periotest values	At placement (%)	At 1 month (%)	At 3 months (%)	At 6 months (%)	At 9 months (%)	At 1 year (%)
−0.8-0	33 (94.0)	33 (94.0)	31 (88.0)	28 (80)	28 (0.0)	28 (80)
+1.0-+9.0	2 (6.0)	0 (0.0)	1 (3.0)	0 (0.0)	0 (0.0)	0 (0.0)
+10.0-+50.0	0 (0.0)	2 (6.0)	1 (3.0)	3 (8.0)	0 (0.0)	0 (0.0)
Total	35 (100.0)	35 (100.0)	33 (94.0)	31 (88.0)	28 (80.0)	28 (80.0)

Table 5: Distribution of implant length by the mean periotest values from the time of placement to 1 year

Implant length (mm)	Mean periotest values (SD)					
	At placement	At 1 month	At 3 months	At 6 months	At 9 months	At 1 year
10.0 (25)	−0.29 (0.53)	1.22 (6.31)	0.44 (2.18)	1.72 (7.08)	−0.46 (0.21)	−0.52 (0.20)
11.5 (1)	0.0 (0.0)	−0.30 (0.0)	−0.30 (0.0)	−0.30 (0.0)	−0.40 (0.0)	−0.50 (0.0)
13.0 (9)	−0.46 (0.24)	−0.46 (0.24)	−0.20 (0.67)	0.93 (3.87)	−0.46 (0.13)	−0.49 (0.18)
Total	−0.31 (0.47)	0.75 (5.35)	−0.03 (1.85)	1.45 (6.23)	−0.46 (0.19)	−0.51 (0.19)

SD: Standard deviation

Table 6: Correlation of implant length by total mean periotest score

Implant length (mm)	Mean periotest (SD)	Spearman's rho correlation coefficient	*P*
10.0	1.72 (9.57)	−0.27	0.878
11.5	−1.80 (0.0)		
13.0	−1.08 (3.51)		
Total	0.90 (8.32)		

SD: Standard deviation

anterior and posterior segments of both jaws ($P < 0.05$) [Table 10].

Table 11 shows that 28 implants survived. Initially, 33 implants had an initial periotest value of − 0.8–0 (Category I), of which 28 survived; however, the two implants with an initial periotest value of +1–+9 failed. There was a statistical significant association between the periotest values at placement and implant survival with those who survived having a lower initial periotest value [Figure 3].

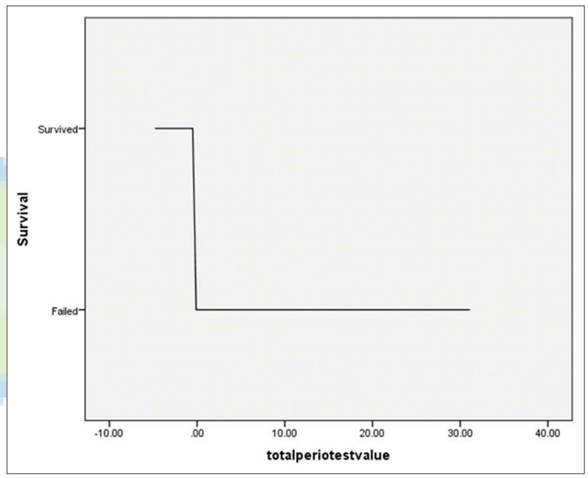

Figure 3: Relationship between periotest value and implant survival

DISCUSSION

This present study sought out to determine the stability of dental implants using the immediate loading protocol with a view to justifying its use in rehabilitating individuals with missing teeth. Implant length and diameter are two major implant-related factors determining the primary implant stability as well as the ultimate success of placement. The implant lengths used in this study are between 10 and 13 mm. Periotest values were used as a measure of implant stability in this study with negative and smaller periotest values indicating greater implant stability and higher values above +9, indicating reduction in implant stability and higher clinical degree of tooth mobility.[9] We found that 11.5 mm implants were most stable with a mean periotest value of −1.80 ± 0.0 while 10 mm implants had the highest mean periotest score of 1.72 ± 9.57. The reason for this may be due to the low number of 11.5 mm implants used in this study. A negative correlation between implant length and implant stability was observed, but this was not statistically significant. Our finding is in contrast with a report which revealed a positive significant correlation between implant length and implant stability.[10] The reason for the variation in our findings may be due to the differences in the location of the implants in both studies. Their implants were placed mainly in the posterior mandible alone which is the best anatomic site to obtain maximum implant stability,[10] while in the present study, the implants were placed in all segments of the jaws.

Table 7: Distribution of implant diameter by the mean periotest values from the time of placement to 1 year

Implant diameter (*n*)	Mean periotest values (SD)					
	At placement	At 1 month	At 3 months	At 6 months	At 9 months	At 1 year
3.7 (11)	−0.10 (0.74)	2.25 (9.07)	−0.51 (0.20)	1.49 (6.37)	−0.53 (0.19)	−0.59 (0.18)
4.1 (17)	−0.41 (0.23)	0.24 (2.65)	−0.26 (0.51)	2.13 (7.43)	−0.43 (0.16)	−0.46 (0.19)
4.7 (7)	−0.39 (0.32)	−0.39 (0.32)	1.16 (3.91)	−0.32 (0.29)	−0.40 (0.24)	−0.51 (0.17)
Total	−0.31 (0.47)	0.75 (5.35)	−0.03 (1.85)	1.45 (6.23)	−0.46 (0.19)	−0.51 (0.19)

SD: Standard deviation

Table 8: Correlation of implant diameter by total mean periotest score

Implant diameter (mm)	Mean periotest (SD)	Spearman's rho correlation coefficient	*P*
3.7	2.13 (11.55)	−0.75	0.668
4.1	0.76 (7.42)		
4.7	−0.67 (4.20)		
Total	0.90 (8.32)		

SD: Standard deviation

Table 9: Distribution of site of implant placement (maxilla and mandible) by mean periotest score

	Maxilla	Mandible	*T*	*P*
Mean periotest value	1.95	−2.12	2.147	0.041

P<0.05

Table 10: Distribution of location of implant placement (anterior and posterior) by mean periotest score

	Maxilla		Mandible	
	Anterior	Posterior	Anterior	Posterior
Mean periotest value (SD)	2.02 (9.65)	1.81 (9.65)	−1.50 (1.27)	−2.30 (1.23)
T	0.053		0.807	
P	0.958		0.446	

P>0.05. SD: Standard deviation

Table 11: Comparison of periotest values at placement and survival of implant

Periotest at placement	Survived (%)	Failed (%)	Total (%)
−0.8-0	28 (80.0)	5 (14.3)	33 (94.3)
+1.0-+9.0	0 (0.0)	2 (5.7)	2 (5.7)
Total	28 (80.0)	7 (20.0)	35 (100.0)

P=0.001 (<0.05)

We further investigated the relationship between implant diameter and implant stability. It was observed that 4.7 mm implants had the lowest mean periotest value (−0.67 ± 4.20) followed by 4.1 mm implants (0.76 ± 7.42) and 3.7 mm implants (2.13 ± 1.55).

There was a negative correlation between implant diameter and implant stability which was not statistically significant and is in agreement with previous studies.[10,11] Previous studies have documented that implant diameters are positively correlated to implant stability. This is because of the larger contacting surface of the implant with bone. This study achieved a high primary implant stability for all cases (mean torque = 45 N-cm) as a result of the careful osteotomy preparation as well as the use of tapered and screw implant designs. It has been reported that screw design improves primary stability, the principal requirement for immediate loading success.[12-15]

There was a statistically significant association between initial periotest value at placement and implant survival, indicating that the periotest value at placement affects the 1-year survival rate of the implants. This is in agreement with what is obtained in other reports.[16,17] An initial periotest value is necessary for implant survival as it shows that the implant is well integrated into the bone with little or no mobility and can be loaded deterring prosthetic loading of an unstable implant.

Significantly, lower mean periotest value was recorded in the mandible (−2.12) compared to the maxilla (1.95), indicating better implant stability in the mandible than in the maxilla. This is in agreement with the findings of majority of similar studies.[18,19] Our result is however in contrast with the findings of a study carried out by Oh *et al.*,[20] which showed better periotest values in the maxilla than in the mandible. The reason for this may be attributed to the different study subjects as animal subjects (mongrel dogs) used by the investigators as opposed to human subjects used in our study.[20] Further, the better (low) periotest value obtained in the mandible may be due to the better volume and density of bone available for osseointegration.[19]

In the maxilla, lower periotest values were obtained in the posterior region compared to the anterior region although this was not statistically significant. Similarly, in the mandible, lower but insignificant periotest values were obtained in the posterior region compared to anterior region. These results are in contrast with a study by Cranin *et al.*,[10] where lower mean periotest values were obtained in the anterior segments of both the maxilla and mandible. The reason for this may be attributed to a significantly large number of implants placed in the anterior region of the maxilla and mandible in the present study as opposed to the posterior region.

CONCLUSION

There is a definite relationship between implant characteristics and implant stability of immediately loaded implants. This is denoted by a negative correlation between implant length, diameter, and the periotest values, denoting that implant stability increases as the length and diameter increases. Immediately loaded implants placed in the mandible tend to be more stable than those placed in the maxilla, with the initial stability at implant placement having a significant association with the implant stability after 1-year of follow-up.

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Conflicts of interest

There are no conflicts of interest.

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