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Immediate Loading Dental Implants: Can Resonance Frequency Analysis or Micro-Roughness be Guidance: A Prospective Study

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ABSTRACT

This study was designed to evaluate the effect of different surface preparations and macro design on the stability of implants through resonance frequency analysis and insertion torque. 4 commercially available dental implants were compared for in-vitro and in-vivo application. In vitro application, surface roughness was assessed with surface stylus profilometry. As an in-vivo application, 49 dental implants spread over different systems were placed in equivalent number of patients and rehabilitated for missing permanent mandibular first molar using implants dimensions of approximately 4 mm diameter and 10mm length. Insertion Torque (IT) and Resonance Frequency Analysis (RFA) values during implant placement were recorded for each case. Stability values using RFA were re-assessed at 1- and 12-months follow-up. Surface roughness of dental implants ranged for 0.46 µm to 4.38 µm for each system. Both the ISQ and insertion torque varied significantly with the variation in surface texture and macro design. Despite variations in surface roughness, IT and ISQ values, all implant systems showed successful immediate loading and good clinical performance. Considering the variation in surface values depending on instrument used, it is necessary to conduct comparative studies between different surface assessment instruments to quantify this difference. Further, more studies with larger sample size should be conducted to further substantiate the obtained results.

Keywords: Dental implants; Immediate Dental Implant Loading; Osseointegration; Resonance Frequency Analysis (RFA); Osstell study

1. INTRODUCTION

Dental implant-based rehabilitation of a single missing tooth has seen a paradigm shift from a two-staged protocol to immediate loading of placed implants. Whether the latter can be clinically undertaken or not is determined by the achieved primary stability which depends on multitude of factors like host bone quality, implant design and topography.[1,2]While the host bone quality is not under the clinician's control, the other two parameters can be varied to achieve the best possible results.

The surface topography of the implant plays a critical role in achieving better osseointegration, which can be achieved by using physical, chemical, or mechanical methods. The surface roughness is the key factor in determining the primary stability of the implant because of high Bone-to-Implant Contact (BIC). To assess the surface topography of the implant SEM, EDX and profilometry are used. To determine the roughness of the implant optical and surface profilometry is used.[2,3]

Implant stability can be determined using invasive or non-invasive methods. Periotest and Insertion Torque (IT) values are popularly used, time tested non-invasive methods, however, the former has shown poor sensitivity wherein the recorded results are susceptible to variations while the latter cannot be used for assessment of secondary stability.[3] Being non-invasive and having the advantage of recording primary as well as secondary stability, Resonance Frequency Analysis (RFA) provide a viable assessment alternative.[2,4] However, regular use of RFA is elusive in clinical practice, thereby warranting for more literature concerning its clinical application.

A previous study by the same authors assessed the roughness of the various commercially available implants and suggested the conduction of a clinical trial to compare the correlation between the implant stability and surface roughness. So, in the continuation current study was done to evaluate the effect of different implant topography on implant stability using IT and RFA.

1.1 Aim

To compare surface roughness, IT and RFA values obtained using Osstell ISQ® for different dental implant systems.

1.2 Objectives

- To determine surface roughness values of four dental implant systems using stylus surface profilometry.

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- To determine IT and primary RFA values of the implants during placement.
- To record secondary RFA values after 1 and 12 months respectively.

2. METHODOLOGY

The study was done in the Department of Dental Research and Implantology, Institute of Nuclear Medicine and Allied Sciences (INMAS), Defence Research and Development Organisation (DRDO), New Delhi, from January 2018 till March 2020. Ethical approval was obtained from the Institutional Ethical Committee (INM/IHEC/2017/05). Written, informed consent was taken from all patients to be a part of the study.

2.1 In-vitro Application

2.1.1 Determination of surface roughness

Surface roughness of the four implants was determined using stylus surface profilometer (Dektak 150 Surface Profiler, Veeco, USA). Concerned implant was mounted in an inverted position to determine the roughness on the flat apical portion in linear direction. Profilometry scan was done using standard scan type, with a stylus of radius 2.5 µm and length 700.0 µm and a force of 3.00mg. Scan duration was set at 45seconds.

2.2 In-vivo Application

Patients reporting in the department during the concerned duration and meeting the inclusion criteria were included in the study. Thus, a convenience sample was taken as a pilot attempt for the study and no sample size calculation was conducted. Depending on the available edentulous space, patients were rehabilitated using one of the four commercially available dental implant systems (average size of dental implants: diameter: 4mm, length: 10 mm) and divided into four corresponding groups. The four groups were rehabilitated using:

Group 1: IndidentTM Dental Implant System
Group 2: AB© Dental Implant System
Group 3: Adin© Dental Implant System (TouaregTM-S)
Group 4: BioHorizon® Dental Implant System (Tapered internal implant)

2.3 Inclusion Criteria

- Patients more than 18 years of age.
- Patient requiring replacement of permanent manidbular first molar tooth which can be rehabilitated using dental implant.
- Systemically healthy patients.
- Minimum occlusogingival space of 7 mm in edentulous region.
- Minimum mesiodistal space of 7 mm and vertical bone height of 12 mm between the alveolar crest and Inferior Alveolar Nerve (IAN) canal in the edentulous region.
- Healed bone crest (at least three months after extraction or tooth loss).

2.4 Exclusion Criteria

- Patients not willing to be a part of the study.
- Patients with history of smoking and/ or bruxism.
- Patients with co-morbidities like uncontrolled diabetes mellitus (HbA1c >7%), myocardial infarction within last two months, coagulation and/ or bleeding disorders

2.5 Pre-operative Assessment

All patients were subjected to clinical and radiological assessments to determine the feasibility of dental implant placement. Clinical assessment included determining the mesiodistal space in the missing region and occluso-gingival dimensions to check the feasibility of prosthetic rehabilitation. Radiographic assessment was done using orthopantogram (OPG) to determine the bone dimensions in the edentulous region and proximity to vital structures. Implant planning was done such that there was at least 1.5 mm distance from the adjacent teeth and 2 mm from IAN canal.[5] A diagnostic impression was recorded for all patients using irreversible hydrocolloid impression material (Dentsply Zelgan 2002, Dentsply) for fabrication of surgical stent for ascertaining the accurate position for dental implant placement.

2.6 Operative Procedure

All dental implants placement surgeries were performed under local anesthesia using 2 % lignocaine hydrochloride with 1:80,000 adrenaline (Lignospan special, Septodont Healthcare India Pvt. Ltd.). All bone drillings were performed using implant surgical kits of respective manufacturers and using torque values between 25-35 Ncm.

A transverse incision was given on the edentulous ridge to reflect a mucoperiosteal flap. This was followed by positioning of the surgical stent in place and using the 2 mm diameter pilot drill at 1,500 rpm in the planned position. The made drill indent was progressively enlarged using sequential drill sizes according to manufacturer's guidelines till the desired diameter and length were achieved. The dental implant was then placed into position using motor driven handpiece and the corresponding torque values were recorded. The mucoperiosteal flap was then approximated and sutured in placed using resorbable, 3-0 vicryl suture (Ethicon Inc., United States) using interrupted sutures.

Post implant placement, RFA values were recorded using Osstell ISQ® (Osstell AB, Göteborg, Sweden). To record the ISQ value, the area around the implant was cleaned and made free of any bone or soft tissue debris. Osstell®Smartpeg was mounted on the dental implant using Smartpeg mount using finger torque of approximately 5Ncm. The mount was removed and ISQ values were checked in two mutually perpendicular positions, i.e., mesiodistal and labiolingual position. A mean of the two values was recorded as the final value. Final ISQ values were interpreted as follows:[6]

ISQ<60: Low stability

ISQ 60-69: Medium stability
ISQ≥70: High stability; suitable for immediate loading

All implants were rehabilitated using non-functional temporary prosthesis made of acrylic resin (3MTM ESPETMProtempTM 4 Temporization material).

2.7 Patient Follow-up

First follow up was done after 1 month of implant placement. The temporary prosthesis was removed, ISQ values re-evaluated and a definitive porcelain-fused-to-metal (PFM) crown was cemented in place.

A second follow up was done 12 months after dental implant placement. The implant site was clinically and radiographically assessed for signs and symptoms of implant failure.[7] RFA values were re-recorded at this time (Fig. 1).

2.8 Statistical Analysis

SPSS Version 24 was used for statistical analysis.

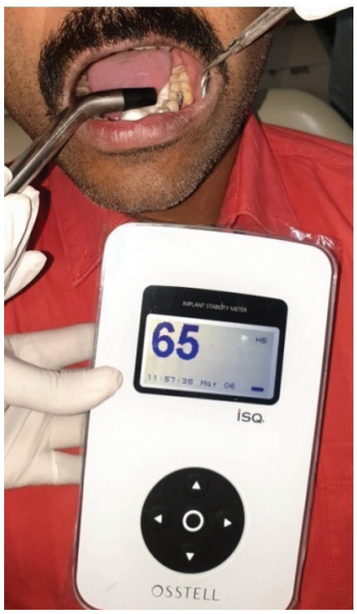

Figure 1. ISQ assessment after 12 months

Descriptive analysis of the complete data was performed. Pearson correlation was used to check association between primary implant stability values and IT values, stability values at 1- and 12- months and 12-month stability value and surface roughness. Analysis of variance (ANOVA) was performed to find variability between different implant systems. Significance value was set at $P<0.05$.

3. RESULTS

31. In-vitro Assessment

3.1.1 Stylus Surface Profilometry

Evaluated implants showed variation in their surface roughness values. Minimum surface roughness was exhibited by AB© Dental implant system (0.46 µm) while maximum surface roughness was shown by Adin© implant system (4.89 µm) (Fig. 2 and Table 1).

Table 1. Surface roughness values of different dental implant systems

Implant System	Average Roughness(in µm)
Indident™ Dental Implant	1.11
AB© Dental Implant	0.46
Adin© Dental Implant	4.89
BioHorizon® Dental Implant	4.38

3.2 In-vivo Assessment

3.2.1 Descriptive statistics of in-vivo application

A total of 49 dental implants were placed in equal number of patients. The patients age ranged from 24 to 65 years (mean= 44.33±11.08 years) with 14 females and 35 males. Each group consisted of 16, 14, 11 and 8 dental implants, respectively. At the time of primary RFA value recording, minimum recorded ISQ was 49 and maximum was 98. All implants were immediately loaded. At the two follow-ups performed at 1 month and 12 months post placement, no implants were lost, thereby having a 100% clinical success rate. The obtained minimum and maximum IT and primary ISQ values for each system are presented in Table 2.

3.2.2 Surface Roughness and IT and Primary ISQ Values

Adin© dental implants exhibited the maximum surface value of 4.89 µm. Correspondingly, none of the 11 implants of this system exhibited IT of less than 32 Ncm (mean = 39.59 Ncm±4.76). Mean recorded primary ISQ was 71.45±9.59. BioHorizon® Dental Implant showed the next highest roughness value of 4.38 µm. For the eight BioHorizon® implants the IT ranged from 31 Ncm to 45 Ncm (mean=38.13 Ncm±4.96) while the mean recorded ISQ was 78.63±12.21). IndidentTM dental implants presented the second lowest roughness value of 1.11 µm. None of 16 implants placed, none had an IT value of less than 36 Ncm except one. Mean recorded primary ISQ was 68.81±7.56. With the minimum surface roughness value, 14 implants belonged to AB© system. They presented mean IT and ISQ of 39.59Ncm±4.76 and 71.45±9.59, respectively.

3.2.3 Correlation of IT and Primary ISQ Values

Positive correlations were seen for groups 1 and 2 with r values of 0.108 and 0.638 and P values of 0.691 and 0.014, respectively for the two groups. Negative correlation was seen for groups 3 and 4 (r values of -0.167 and -0.418, Pvalues of 0.624 and 0.303 respectively). Cumulatively, there was no significant correlation between IT and primary ISQ values (r value = 0.50 and P value = 0.732).

3.2.4 Correlation Between ISQ Stability Values at 1 Month and 12 Months

A significantly high correlation with a nearly perfect

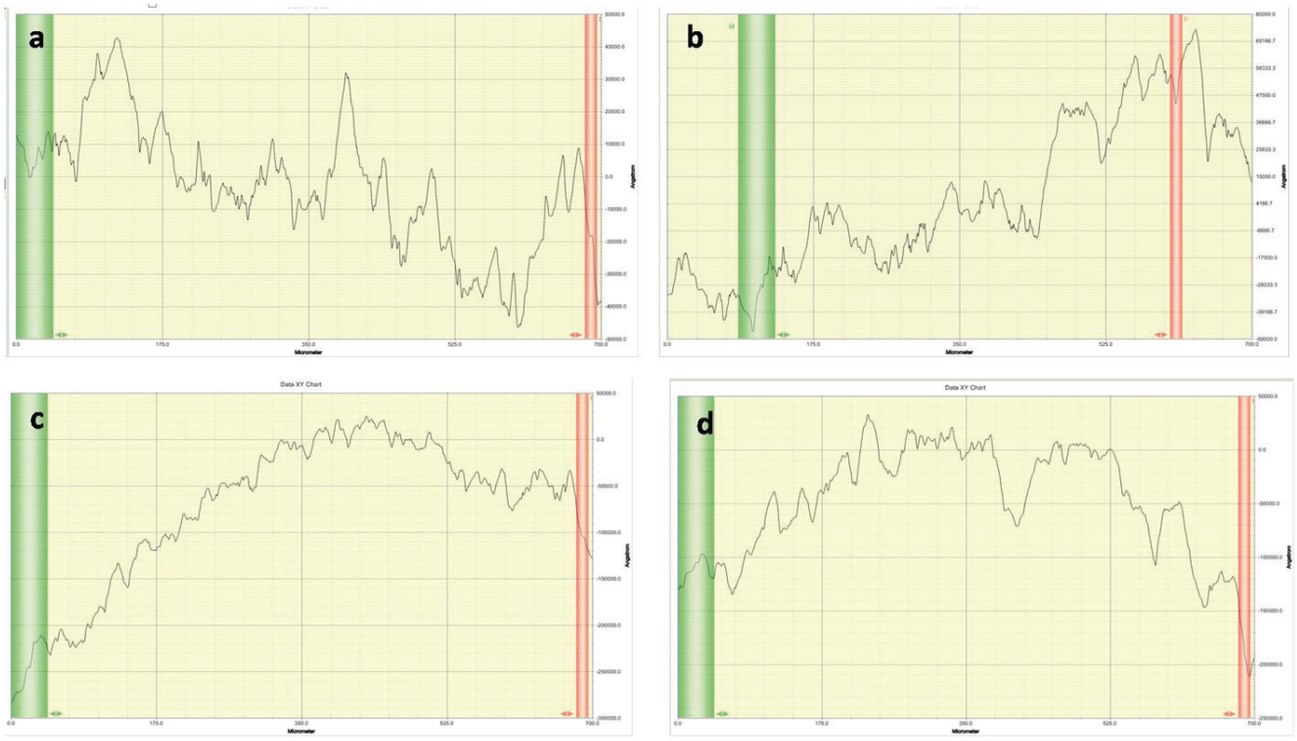

Figure 2. Surface stylus profilometry results of: (a) IndidentTM Dental Implant; (b) AB© Dental Implant; (c) Adin© Dental Implant; and (d) BioHorizon® Dental Implant.

Table 2. Minimum and maximum IT and ISQ values for different implant systems

Implant System	Insertion Torque (in Ncm)		Primary ISQ		ISQ at 1 month		ISQ at 12 months	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Indident™	30	45	49	81	50	82	42	79
AB©	31	50	53	83	52	82	49	81
Adin©	32	45	56	84	57	85	54	80
BioHorizon®	31	45	58	98	59	92	54	89

positive correlation was seen between the two recorded stability values for individual implant system groups as well as for the cumulative data (P value <0.01). Individually, in terms of absolute values, there was a decrease in the obtained minimum and the maximum ISQ values at 1 month and 12 months respectively for each implant system.

3.2.5 Correlation Between ISQ at 12 Months and Dental Implant Surface Roughness

Cumulatively, there was no significant positive correlation between implant surface roughness values and ISQ at 12-months (r value = 0.195 and *P* value = 0.179).

4. DISCUSSION

In our previous study, the roughness of the various commercially available implants was assessed and the conduction of the clinical trial to compare the correlation the implant stability and surface roughness was proposed. So, the current study mainly aims to evaluate the effect of different implant topography on implant stability using IT and RFA.

Primary and secondary implant stabilities play a critical role in determining the future osseointegration, the key to successful implant treatment. Micromotion values of 50 µm to 150 µm are considered to be well tolerated in order to avoid threatening of the clinical outcomes of the placed implant.[2] These micro movements rather help in stimulating the bone under physiologic conditions which helps in enhanced bone remodelling and achieving osseointegration.[2] All being said, these micromovements are strongly dependent on primary stability which is a mechanical phenomenon guided by local bone density, operative technique and macro and

micro features of dental implant likeshape, size (length and diameter), implant pitch, number and design of threads and surface topography.[2] In contrast, secondary implant stability is determined by the bone-implant interface which is dictated by bone quality, implant topography and patient factors.[1]

Surface roughness at the micrometer level is considered the most important in dictating the success of dental implant treatment with rougher implants presenting a high bone-to-implant contact (BIC).[8,9] Based on obtained surface arithmetical mean height (Sa), "Albrektsson and Wennerberg characterized dental implant surface into 4 types as, smooth (Sa<0.5 μm), minimally rough (Sa: 0.5-1.0 μm), moderately rough (Sa: 1.0-2.0 μm) and rough (Sa: >2.0 μm)wherein, at least a moderate implant roughness is considered desirable for high initial survival rate".[2,10,11]

According to this categorization, AB© dental implants (0.46 μm) are smooth, IndidentTM implants (1.11 μm) are moderately rough while Adin©(4.89 μm) and BioHorizon®(4.38 μm) implants are rough. "In a previous study done by the author,12 surface roughness was assessed using optical profilometry wherein higher values were obtained for AB© implants compared to BioHorizon®". However, in our study, stylus surface profilometry showed the opposite results. This can be due to the reason that roughness values are influenced by the type of instrument used, as was concluded by Kohles, [13] *et al.* They also expressed technical difficulties in recording roughness values for Indident TM implants which was not encountered in our study.

Comparing the cell response to different implant surfaces, "Andrukhov *et al*,[14] found significantly higher Sa values for rough titanium surface implants compared to zirconia surface implants". In terms of various gingival and inflammatory markers, slightly higher levels of Porphyromonasgingivalis lipopolysaccharide (LPS) induced interleukin (IL)-6 and monocyte chemoattractant protein (MCP)-1 were seen on titanium surface with no difference in levels of IL-1β induced IL-6. Thus, it is speculated that varying expression of these inflammatory markers play a significant role in determining the future peri-implantitis. Surface roughness plays an important role in implant osseointegration, however, there is no single value or range cited in literature that is considered optimal for achieving the same.[15]

Providing the advantage of being non-invasive, recording of IT at the time of implant placement and ISQ values using RFA technology have shown to play a vital role in determining the primary implant stability and osseointegration.[16,17] Previous studies have shown that a minimum of 32Ncm IT should be achieved to ensure osseointegration while minimum value of 35Ncm is desirable to perform immediate implant loading.[17,18] It is also advocated that IT should not exceed 50Ncm in order to avoid peri-implant bone loss which is contrary to the observations of "Greenstein *et al* who found that IT of more than 50 Ncm helps reduce micro-movements of the placed implant".[17,19] In our study, IT of 30Ncm and 50Ncm were recorded for one patient each. For the remaining implants, IT value ranged from 31Ncm to 47Ncm. No implant was lost during the follow up period due to any clinical or radiological complications.

ISQ recording is considered valuable as it provides information concerning axial stability of the placed implant immediately after placement as well as during healing period.[20] Stability values of 65 or above are considered reliable to perform immediate loading while values of less than 45 indicate towards poor primary stability.[2,6,21] In our study, 39 (79.59 %) of the total placed implants had a primary ISQ of 65 or more. The remaining implants, although exhibited low values, showed successful implant healing. Previous studies have shown that there is only slight difference in the recorded primary stability values and values recorded after 3 to 4 weeks of healing, whereas there is a significant increase in ISQ values seen thereafter.[22] In our study, we too found a significantly high correlation (P value <0.01) between the ISQ values recorded at 1 and 12 months respectively, irrespective of the dental implant system used.

Correlating IT with ISQ, varied observations have been noted in literature. Recording ISQ values at designated time intervals, "Simmon, *et al.* found a positive relation between the two values however no relation was found in the values recorded at the time of implant placement".[23] Dividing the IT into three groups of low, medium and high torque groups, "Baldi, *et al.* found IT and ISQ to be correlated for medium torque group, however, this was not the case for the remaining groups".[24] Working individually,"Acil, *et al.* and Wagenberg, *et al.* also did not find any correlation between IT and ISQ".[25,26] In our study, we did not find a significant correlation (P value = 0.732) between the two values and thus the results were in line with the previous studies.

5. CONCLUSION

In conclusion, Adin© and AB© Dental Implant Dental Implant have highest and lowest surface roughness respectively. The immediate loading of single dental implants with minimum IT of 30Ncm and primary ISQ of 49 has shown successful results thereby helping in reducing treatment time. A significant amount of decrease in ISQ values is seen at 1 and 12 months post-operatively. There was no significant positive correlation found between implant surface roughness values and ISQ at 12-months. To further substantiate these findings, the authors propose that more studies comparing different implant systems and with larger sample size be conducted using a similar study protocol so that it can be adopted with confidence in regular clinical practice.

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