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Evaluation of Stability And Crestal Bone Loss of Dental Implants Subjected to two Loading Protocols in the Mandible.

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Abstract
Purpose: The aim of this study was to assess the primary and secondary stability and crestal bone loss of dental implants subjected to immediate loading and delayed loading by using resonance frequency analysis.
Materials And Methods: The study consisted of placement of 30 ADIN TOURAEG S IMPLANTS on patients with edentulous spaces present in the mandibular posteriors. Patients were assessed based on inclusion and exclusion criterias and selected for implant placement. 30 implants were randomized and allocated into two groups i.e; Delayed loading group and Immediate loading group. In Delayed loading group implants were placed using the two stage surgery protocol and in Immediate loading a single stage surgery protocol was used. Implant diameter and length were decided based on diagnostic aids such as CBCT and Bone Mapping. Primary and secondary stability were recorded using the resonance frequency analysis(RFA) device at the day of surgery, after 1 week, after 1 month, after 3 months and after 6 months. Crestal bone loss difference was measured using the RVG at the 6th month.
Results: 15 implants were placed in the delayed loaded group(Group 1) and 15 implants were placed in the immediate loaded group(Group 2). 1 implant had failed in group 1 and 2 had failed in group 2. When comparing baseline datas and values obtained by Osstell RFA device after 6 months there was a significant difference in stability values of both the groups, where immediately loaded implants showed a slightly higher stability values (P=.036). There was no statistical significance with respect to crestal bone loss after 6 months when both the groups were compared.
Conclusions: Implants can be successfully placed and loaded immediately in the mandibular posteriors if good primary stability is achieved during the initial placement of implants. This procedure decreases treatment time and patient discomfort. RFA can be used as a useful predictor in determining stability and success of implants.

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I. Introduction

Missing teeth and supporting oral tissues are being replaced with implants to restore chewing function, speech, and aesthetics. There is a direct structural and functional connection between living bone and implant surface, termed osseointegration, which was first described by Brånemark in 1977[1] **.** Initially, the prosthesis was loaded three months after the placement of implant. Now treatment time can be shortened by loading the implant immediately after implant placement (immediate loading of implants). This protocol results in patients having fewer surgical sessions, shorter treatment periods, improved bone healing[2,3] and facilitates soft tissue shaping**.** A high degree of clinical success had been observed with this surgical protocol[4]. Implant stability is a measure of the clinical immobility of an implant, which is an important requisite characteristic of osseointegration[5]. Implant stability is achieved at two levels: Primary and secondary stability. Primary stability is achieved at the time of implant placement. Secondary stability depends on bone remodelling at the implant bone interface and is influenced by the implant surface and the wound healing time. Stabilization of implants in the surrounding lamellar bone has been standardized using a variety of techniques including the Periotest, Resonance frequency analysis(RFA) and Cutting torque resistance analysis[6]. RFA is a non invasive intraoral method designed to reflect the bone/implant interface and may be useful in documenting clinical implant stability**.** This device has documented healing changes along the implant bone interface by measuring the increase/decrease in stiffness of the implant in the surrounding tissues. RFA also has been used to determine whether implants are sufficiently stable to receive the final restoration or to be loaded and to identify “at-risk” implants[7].

II. Materials And Methods

The study consisted of placement of 30 ADIN TOURAEG S IMPLANTS on patients with edentulous spaces present in the mandibular posteriors. Patients were assessed based on inclusion and exclusion criterias and selected for implant placement. 30 implants were randomized and allocated into two groups i.e; Delayed loading group and Immediate loading group(Fig 2). In Delayed loading group implants were placed using the two stage surgery protocol and in Immediate loading a single stage surgery protocol was used. Implant diameter and length were decided based on diagnostic aids such as CBCT and Bone Mapping. Primary and secondary stability were recorded using the resonance frequency analysis(RFA) device at the day of surgery, after 1 week, after 1 month, after 3 months and after 6 months (Fig 3). Implant stability quotient (ISQ) values were recorded in both mesiodistal and buccolingual direction.

Crestal bone loss difference was measured using the RVG at the 6^{th} month. An RVG was made immediately after implant placement . The perpendicular distance was measured between the apical end of the implant body and the top of the crest of the ridge on the distal side of the implant . Similarly, the perpendicular distance between the apical and coronal end of the implant body was also measured. In situations where the coronal end was not identifiable from the abutment, the physical distance from different identifiable point (such as the first thread) to the tip of the implant body was obtained from the manufacturer. The following formula was used: Bone level at baseline=[(C baseline×- Physical length of implant body)/I baseline], where I was subject to the ability to detect the implant shoulder easily on a radiograph (Figure 1). The average values of the mesial and distal side was taken to estimate overall bone level. The bone levels were calculated at subsequent recall appointments as described. The crestal bone change was calculated as follows: Crestal bone change (at given time)=(Bone level at baseline-Bone level at that time)[8].

III. Results

The mean insertion torque applied in both groups (Delayed loading and Immediate loading) is presented in Table 1. Out of 15 delayed loaded implants, 14 implants were successfully osseointegrated with a mean torque value of 61.43±22.9. Out of 15 immediately loaded implants, 13 implants were successfully osseointegrated with a mean torque value of 60±20.8. Table 2 presents the mean ISQ values recorded by the Resonance Frequency Analysis device for delayed loaded(DL) and immediately loaded(IL) implants. ISQ values were recorded in the mesio-distal direction as well as bucco-lingual direction during 1^{st} day and after 1 month, 3 months and 6 months. It clearly shows that the mesio-distal ISQ value is greater than the bucco-lingual ISQ value for both the loading protocols. There is also decrease in the ISQ values after 1 month of implant placement in both the groups (DL=67.4 , IL=68). The ISQ values increased gradually after 3 months and 6 months. The ISQ values after 6months were almost similar to the ISQ values obtained during implant placement and there was no statistical significance. The mean ISQ values (Table 3) between readings recorded during the 1^{st} day and 1 month, 1 month and 6 months were statistically significant (p=0.001). The mean ISQ value recorded after 6 months for conventional loading was 72.7 and for immediate loading it was 74.9. The ISQ values between conventional loading and immediate loading (Table 4) showed statistical significance (p=0.036). Table 5 compared of mean ISQ values for both groups recorded in both the directions using the RFA and there was no statistical significance found among all the groups except for the ISQ values obtained during the 6^{th} month in the mesiodistal direction. Table 6 compared the crestal bone loss recorded in both the groups. It was noticed that there was no significant difference in crestal bone loss when both the groups were compared, as conventional loaded implants had a mean crestal bone loss of 0.77mm and immediately loaded implants had a mean crestal bone loss of 0.80mm. Graph 8 and graph 9 shows the success rate/failure rate of immediately loaded implants(87%) and conventionally loaded implants(93%). 2 implants had failed from the immediately loaded group and 1 failed from the conventionally loaded group. The failed implants showed good degree of primary stability during placement but these implants became mobile before recording the RFA values within 1 month.

IV. Discussion

The success of dental implant treatment is influenced by both the quality and quantity of available bone for implant placement. Both these factors play an important role in determining the implant stability[9]. Dental implant stability is a measure of the anchorage quality of an implant in the alveolar bone and is considered to be the consequential parameter in implant dentistry. Implant stability can be divided into Primary stability and Secondary stability. Primary stability of an implant is achieved by mechanical engagement with the bone at the time of placement of the implant[10]. It prevents the formation of fibrous connective tissue layer between implant and bone, consequently ensuring osseointegration. After osseointegration is established, it is the secondary stability that maintains the biological stability through bone regeneration and remodeling . According to Meredith[5,10,11], there are two main factors that influence the primary stability of implants at placement. First is the amount of bone- implant contact. It was indicated that bone to implant contact increased over a time in bones with higher densities. The second, is the role of compressive stresses at the implant tissue interface. By using the drill that is smaller in diameter than that of the implant, there is marked local compression of the bone when an implant is inserted[12,13]. This can result in hoop stress. Such stress may be beneficial in enhancing the primary stability of an implant, but they can reach a sufficiently high level to result in necrosis and local ischemia of the bone at the implant – tissue interface.

Various methods[11,14,15,16,17,18,19,20] were introduced to predict the success and failure of an implant by determining implant stability. The three most frequently used methods to determine implant stability are Periotest(Germany), Osstell(Sweden) and Osseocare(NobelBiocare,Sweden). Meredith and Sennerby[10], were the first to propose RFA as a highly effective qualitative method to assess implant stability. Many authors[20] have evaluated implant behaviour in different types of bones and confirmed the reliability and robustness of RFA in stability assessment. This device by Osstell was considered to be a novel technique replacing previously advocated techniques for monitoring implant stability. The values obtained from RFA were calibrated as Implant Stability Quotient(ISQ) that numerically ranged between 1-100. ISQ value between 57-82 is considered to have implant success[5]. Thus in the current study RFA was used to determine primary stability that was recorded during the 1st day and secondary stability was recorded after 1 week, 1 month, 3 months and 6 months of implant placement in the mandibular posterior region. Adequate primary stability (74.3±2.5) was achieved when implant was placed in the mandibular posterior region as it had good bone density. The final drill used in this procedure was smaller in diameter than that of the implant placed which contributed in achieving good primary stability. According to various studies[6,22,23], mean stability values in different bone densities were recorded- Type 1 (62.8±7.2), Type II (59.8±6.7), Type III (56±7.8), Type IV (55.0±6.8). It was seen that primary stability was more for Type 1 and least for Type IV bone. Therefore it is clear that, to achieve a good primary stability, good bone quantity and quality is imperative. Previous research[21] have shown a failure rate of 3% when implants were placed in bone type 1,2 and 3, whereas the failure rate was 35% in type 4 corresponding to its thin cortical shell and softer trabecular bone.

Secondary stability was achieved due to good primary stability and bone remodeling processes. According to various studies[21,22] it was noticed that the stability of implants decreased after 1 month of implant placement. This was due to formation of new woven bone that consists of unorganized collagen matrix, having low load capacity due to which the stability of the implant decreases. In this study, the RFA values after 1 month for conventionally loaded implants was 67.21 and for immediately loaded implants it was 68.0, which were comparitvely less when compared to their initial primary stability. After 3-6 months of implant placement there is a marked improvement in the implant stability due to bone remodeling processes. In the current study, this could be the reason for increase in RFA values for conventionally loaded(72.7) and immediately loaded implants(74.9). It was seen that the ISQ values obtained after 6 months were almost similar to the primary stability that was achieved initially. When RFA values were measured from various directions it was found to be greater in the mesiodistal direction(74.92±2.6) when compared to the buccolingual direction(68.23±3.2) after 6 months. This significant difference remained throughout the intervals of the study and was due to presence of more sound bone in the mesiodistal direction.

In 1998, Meredith[11] suggested a non invasive method of analyzing peri implant bone by connecting an adapter to an implant in an animal study. The experimented resonance frequency analysis system was commercially produced as Osstell(Osstell AB, Goteborg, Sweden). Osstell was later followed by Osstell Mentor and Osstell ISQ. This technique is claimed to be useful to assess bone quality for the placement of an implant(primary stability), to monitor bone formation or remodelling(secondary stability) and to estimate the clinical performance of an implant in function. The principle behind this technology is that, when a frequency of audibility range is repeatedly vibrated onto an implant, a resonance occurs in a higher frequency if the bone implant surface is stronger[23]. Osstell uses electronic technology and Osstell ISQ uses magnetic technology.

Many authors[24,25,26] suggested that for immediate loading, single implants must be inserted with a torque greater than or equal to 30Ncm. In the present study, the insertion torque exceeded this in both the groups (Conventional loading mean torque value- 61.43 & Immediate loading mean torque value- 60). Trisi et al suggested that if an implant is placed with 100Ncm torque and is immediately loaded, it is unlikely to have micromovements sufficient to cause fibrointegration. Earlier in another study[27], Trisi histologically evaluated the healing of implants with high torque values (upto 150Ncm with a mean value of 110Ncm); between the first and the 45th day after implant placement and no signs of bone necrosis by pressure was noted. Grandi[25] et al also observed no differences in the peri-implant resorption between implants placed with low or high insertion torque. The values of insertion torque recorded by them ranged between 30Ncm and 100Ncm. Similar observations are made by Meltzer et al with high values of insertion torque with successful osseointegration. In this current study torque values ranged between 40-100 for both conventionally loaded and immediately loaded implants and it showed successful osseointegration.

Conventional Loading Versus Immediate Loading

Studies dealing with immediate loading of dental implants and bone biomechanics showed that bone remodelling depends on continuous adaptation to functional loading and repair of damage subsequent to overload at the bone-implant interface. Immediate loading procedures can be successful only when micromovement at the bone-implant interface remains below a certain threshold during the healing phase. Micromovement is known to cause fibrous encapsulation of the implant only if it is above 150Ncm. The results of this present study are encouraging as immediate loading showed good secondary stability (74.92±2.6) when compared with conventional loading(72.7±2.5). It should be emphasized that the immediately loaded implants were not submitted to direct occlusion for 6 months(non-occlusal loading), although they were used during chewing. According to Zhang[28], immediate loading led to increase of Runx2 expression gene that led to better osseointegration when compared to delayed loading. A significant increase in bone matrix in the callus was also observed thus increasing the bone content around implants subjected to immediate loading. Other clinical trials confirm the absence of significant clinical differences in the survival of immediately and early loaded implants. It is not early or immediate loading that prevents osseointegration; but, excess micromovement during the healing phase interferes with the process of bone repair. All implants achieved high primary stability at placement, and this appears to be the key factor in obtaining the high survival and success rates. Cooper defined three biologic factors to consider for osseointegration to occur with immediate loading:

1. Factors affecting osteogenesis (bone formation);
2. Factors affecting peri-implant osteolysis (bone resorption);
3. Micromotion effects on peri-implant osteogenesis.

Osteogenesis is time dependent so the maintenance of implant stability is critical. The initial stability of the implant reduces in the first 3–6 weeks after placement due to remodelling and initiation of woven bone formation. The implant bone interface thus becomes more susceptible to the effects of micromotion. Clinically, this can be minimized by the reduction of occlusal load.

Marginal bone loss

Adequate crestal bone level was considered to be an important clinical determinant for the success of implants. Marginal bone loss not only causes implant failure but also affects the esthetics due to changes in the gingival contour. The factors causing marginal bone loss are overload, microgap at the implant abutment interface, polished implant neck, trauma during surgical procedure and implant exposure during soft tissue healing. A systematic review of marginal soft tissue at implants subjected to immediate loading or immediate restoration noticed that once immediately loaded or restored implants integrate successfully, they appear to show a soft-tissue reaction with regard to peri-implant area as well as morphologic aspects comparable with those of conventionally loaded implants. According to Alberktsson[29], marginal bone loss of around 1-1.5 mm was found to be common during the first year of implant placement. In this study when the marginal bone loss was measured with a radiograph it was found that there was no significant difference seen in the marginal bone loss of conventionally loaded implants (0.77±0.19mm) when compared with immediately loaded implants (0.80±0.16mm) after 6 months.

Table 1: Mean Insertion Torque Applied In Both Groups

Type of loading	Number of implants	Maximum	Minimum	Mean
Conventional loading	14	40	100	61.43
Immediate loading	13	35	100	60

Table 2: Mean Isq Values For Conventional & Immediate Loading

Type Of Loading	1st Day		1 Week		1 Month		3 Month		6 Months	
	Md	Bl	Md	Bl	Md	Bl	Md	Bl	Md	Bl
Conventional Loading	76.2	69.9	75.6	69.5	67.4	62.3	71.7	66.5	72.7	67.5
Immediate Loading	73.3	68.2	72.7	68.1	68	62.3	72.1	66.9	74.9	68.2

Table 3: P Value For Conventional And Immediate Loading Groups

	MD1D-MD1M	BL1D-BL1M	MD1M-MD6M	BL1M-BL6M
Conventional Loading	.001	.001	.001	.001
Immediate Loading	.001	.001	.001	.001

Table 4: Comparison Of Isq Values After 6 Months For Both Groups

	MEAN ISQ VALUE	P VALUE
Conventional Loading	72.7	.036
Immediate Loading	74.9	

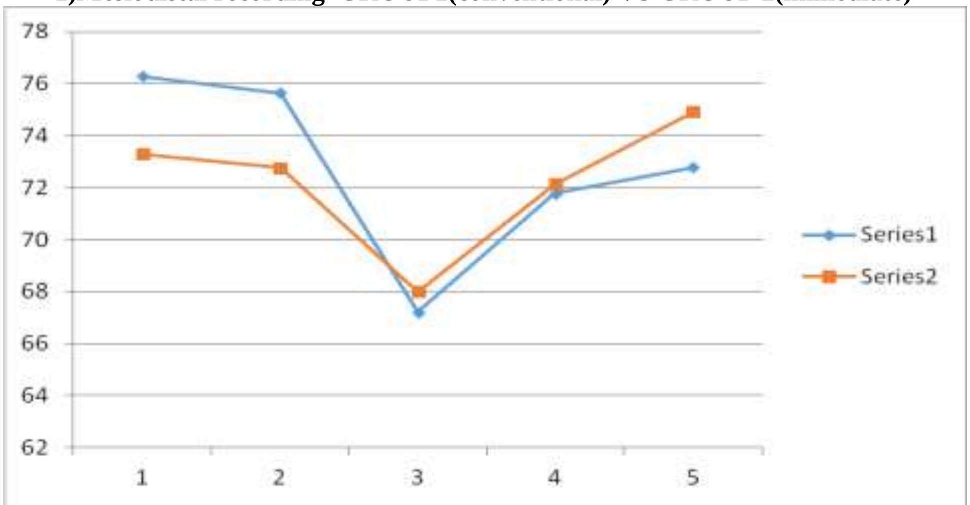
Table 5: Comparison Of Mean Isq Values For Both Groups Recorded In Both The Directions Using The Rfa

	MEAN	P VALUE
MD1W 1	75.6	.068
2	72.7	
BL1W 1	69.5	.319
2	68.1	
MD1M 1	67.2	.506
2	68	
BL1M 1	62.36	
2	62.38	.983
MD3M 1	71.7	.737
2	72.1	
BL3M 1	66.5	.794
2	66.9	
MD6M 1	72.7	.036
2	74.9	
BL6M 1	67.5	.597
2	68.2	

Table 6: Crestal Bone Loss Comparison For Both Groups

	MEAN BONE LOSS	P VALUE
Conventional Loading	.779	.675
Immediate Loading	.808	

1)Mesiodistal recording GROUP1(conventional) VS GROUP 2(immediate)



2)Buccolingual Recording Group 1 Vs Group 2

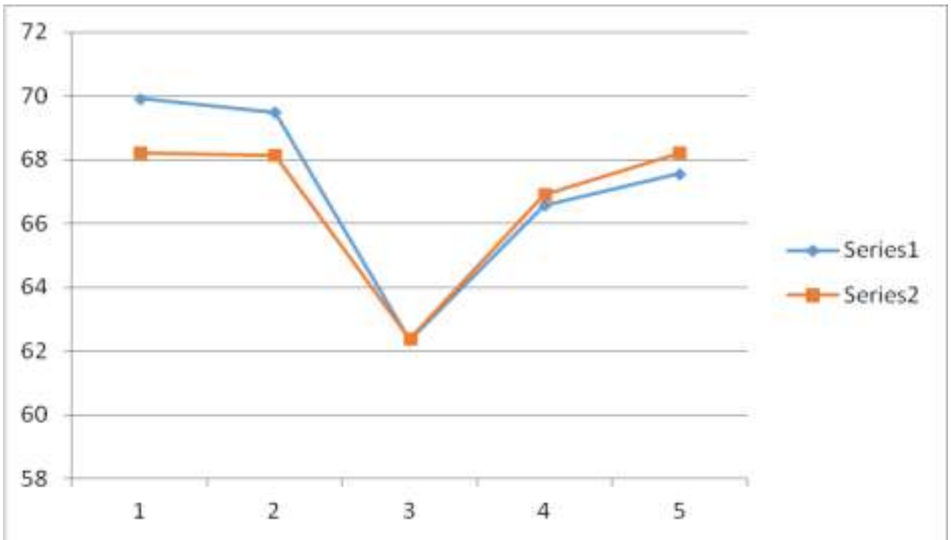


Fig 1- Radiographic reading. Measurement of crestal bone loss

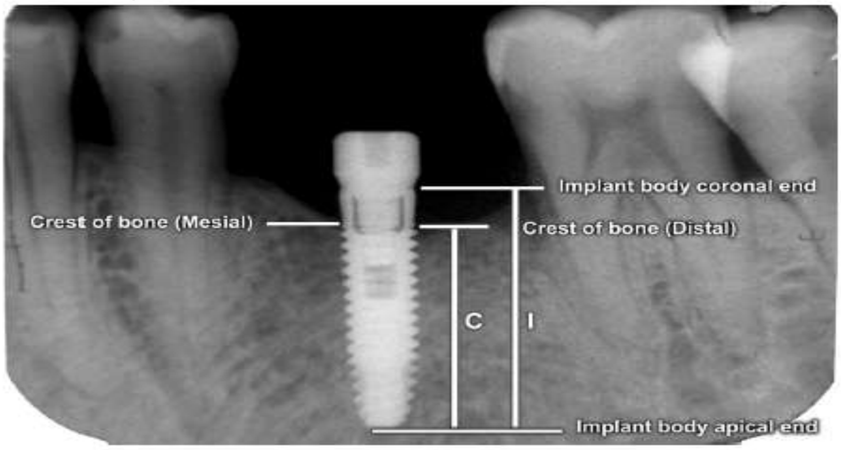


Fig 2- Immediately loaded implant

Fig 3- Recording of Implant stability using Resonance Frequency Analysis

V. Conclusion

Within the limitations of the present study, it is evident that during Immediate Loading the establishment of a good implant primary stability is important. There is sufficient evidence to suggest that the degree of achieved primary stability during IL protocols is dependent on several factors including bone density and quality, implant shape, design and surface characteristics and surgical technique. there is no clinical study today, which proves the RFA level for implants, which survived in a long-term and the necessary minimum RFA threshold we need for the success of IL implants. The resonance frequency analysis technique can supply clinically relevant information about the state of the implant–bone interface at any stage of the treatment or at follow-up examinations. The resonance frequency analysis technique evaluates implant stability as a function of the stiffness of the implant–bone interface and is influenced by factors such as bone density, jaw healing time and exposed implant height above the alveolar crest Further research is required in situations, such as poor bone quality and quantity and multiple implants or augmentation procedures, which may challenge the attainment of primary stability during IL.

- The present study using RFA showed that osseointegrated loaded mandibular implants had a mean ISQ value of approximately 74.
- Immediately loaded implants exhibited slightly higher ISQ values when compared to delayed loaded implants.
- There was no significant difference in crestal bone loss between conventionally loaded implants and immediate loaded implants.

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