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Surgical and Radiographic Parameters to Guide Timing of Implant Loading in the Posterior Mandible

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ABSTRACT

Purpose: Implant placement elicits a cascade of dynamic and unique osteogenic events that differ amongst patients. These differences in the host response have opened the door to early implant loading and has left many clinicians wondering how loading time affects osseointegration. Hence, the main focus of this prospective cohort study was to determine if the incidence of osseointegration for early loaded implants (at 2 months) in the posterior mandible was equivalent to that of implants loaded conventionally (≥3 months). Secondarily, this study aimed to determine if osseointegration could be predicted based on clinical parameters such as percent bone volume (% BV), insertion torque (IT), and implant stability quotient (ISQ). **Materials and Methods:** 21 partially edentulous subjects requiring 22 implants in the posterior mandible were examined. Prior to implant placement, a 2x4 mm bone sample was removed for micro-computed tomography and histologic analyses. Clinical and radiographic parameters including % BV, IT, and ISQ were measured at placement (T0), 2 months (T1), 3 months (T2), and 6 months (T3) post-operatively. At T1, a reverse torque of 20 N cm was applied to the implants and osseointegration was confirmed. Data were statistically analyzed with bivariate regressions, repeated measures analysis of variance, and Tukey post hoc tests. **Results:** At T1, 95% of implants achieved early osseointegration, with osseointegration maintained through T3. The % BV in the bone-tissue core samples ranged from 29% to 82%, and there was a strong, linear relationship between ISQ and % BV ($R^2 = 0.8$). Analyses revealed the difference in measurements between T0 and T1 was the only time point at which the % BV difference was statistically significant ($p < 0.0001$). 82% of patients exhibited the greatest amount of healing in the first recall (at T1) after implant placement. Patients with an initial ISQ score greater than 80 tend to have the least amount of ISQ improvement over time. **Conclusions:** Early loading at 2 months is achievable in the posterior mandible, with equal success to conventional loading. ISQ and IT are the most prognostic predictors of successful early loading when analyzed together.

Keywords: implants, early loading, resonance frequency analysis

1. INTRODUCTION

The American College of Prosthodontists estimates that nearly 48% of Americans are missing one or more teeth. In the next 15 years, this number is expected to exceed 60-70% [1]. An osseointegrated dental implant offers a reliable platform for a definitive restoration and is often considered the treatment of choice for rehabilitation of edentulous sites. However, the decision of when to load an implant prosthesis into function is often performed without careful evaluation of the osseous healing, a necessary pre-requisite for successful osseointegration. Therefore, it remains uncertain on how soon after placement, an implant can be subjected to the forces of occlusion. To complicate this issue, there is an absence of a unified, reliable method to predictably assess osseous healing around an implant and, in turn, osseointegration.

Today, the conventional protocol for implant loading is adopted as an evidence-based practice strategy, which emphasizes an undisturbed, osseous, healing time of at least three months. This conventional guideline has streamlined implant loading into a "one-size-fits-all" process, rendering it, non-conducive to personalized therapy and non-applicable to all implant cases. As such, conventional loading can unnecessarily prolong the time between implant placement and restoration, exacerbating emotional and psychological challenges for our patients. Recently, however, Berglundh et al. showed that the critical steps of implant osseointegration occur between 1 and 6 weeks after implant placement [2]. This indicates that 6 weeks after implant placement, it is biologically possible to load an implant without experiencing a significant shift in the implant's stability, giving rise to the concept of early implant loading.

Furthermore, according to Esposito et al., early occlusal loading is accomplished between one week and two months after implant placement [3]. The principles of early implant loading are rooted in the biomechanical bone-remodeling theory, best known as Wolff's Law [4]. This theory suggests that disuse osteopenia, such as at an unrestored implant site, can rapidly induce a hypoxic state in osteocytes, leading to apoptosis, and on a macroscopic level, an atrophy to bone volume and density. Additionally, Wolff's Law indicates that the longer a site remains unrestored and unstimulated by normal forces of mastication, the more significant the decrease in trabecula, bone density and bone volume at the site will be. Because mechanical feedback regulates bone remodeling by reorienting trabeculae in the direction of the mechanical load, it is advantageous to load an implant at the earliest timepoint – if possible, without jeopardizing the quality of osseointegration. However, on the wrong person, early occlusal loading can have a detrimental effects on peri-implant health. For instance, early occlusal loading could lead to nonconspicuous integration of an implant in a patient with a systemic condition that impairs wound healing, such as diabetes mellitus [5]. Additionally, early loading may not be the best choice for a patient who exhibits parafunctional habits, such as nocturnal bruxism [6]. Therefore, to improve the quality of care rendered, it is critical to evaluate osseointegration on a personalized, or case-by-case, approach.

To select the optimum surgical technique and treatment plan, there is a need for careful analysis of the surgical site, patient biology, and biomechanical principles of osseointegration. Currently, four methods are commonplace for assessing implant stability in clinical practice: insertion torque (IT), reverse torque test (RTT), percussion test (PT), and implant stability quotient (ISQ). However, each of these methods, used alone, is inadequate in defining bone quality or osseointegration in a precise and measurable way, which is essential in designing an implant loading protocol applicable to the different clinical situations.

While the predictive value of implant stability measurements has been repeatedly investigated in many studies, controversy still remains about which clinical parameters can best serve as prognostic factors to guide timing of implant loading and to predict successful implant osseointegration. Indeed, clinical and radiographic parameters remain the primary checkpoint for decision making on implant stability. Perhaps, another important question is whether these "tools" can drive final clinical decision making so clinicians can confidently distinguish patients who are more likely to benefit from early loading verses those for whom conventional loading may be best suited. For example, loading prematurely can lead to implant loss, while loading too late can increase patient's anticipation and lead to patient dissatisfaction due to adverse sequelae such as distress, anxiety, and possibly depression [7]. It is therefore essential that both expediency and precision be at the forefront of treatment planning when deciding to load an implant. As a result, there is a need for information that reliably and accurately quantifies the bone-to-implant contact. Therefore, the aims of this study are two-fold: to compare the incidence of osseointegration for early loaded implants in the posterior mandible to that of implants loaded conventionally and to determine if osseointegration can be predicted based on IT, RTT, PT, and ISQ values along with each patient's clinical presentation. The null hypothesis was: Parameters such as IT, RTT, PT, and ISQ were equally befitted as prognostic determinants for implant stability and osseointegration.

2. MATERIALS AND METHODS:

2.1 Participant enrollment

This clinical research is a prospective cohort study [11, 12] which received 59th MDW (Medical Wing) institutional review board approval and written informed consent from all subjects prior to enrollment in the study. All data collection and surgical procedures were performed in the Post-Graduate Periodontics clinic at Lackland Air Force Base, San Antonio, TX, from June 2019 through June 2020. A power analysis was conducted to determine the number of participants needed in this study. To achieve a power of 0.80 with alpha set at 0.05 level, it was determined that the effect size of 22 implants was sufficient to discern a difference between the incidence of early and conventional loading in the posterior mandible in percent bone volume with a standard deviation of 16.

The following inclusion criteria were applied: (1) Healthy ASA (American Society of Anesthesiology) I and II subjects, > 21 years old, (2) written documentation of a restorative provider (3) planned for implant(s) with subsequent fixed prosthesis in posterior mandible, (4) clinical and radiographic evidence of adequate bone volume, (5) a minimum Modified O' Leary score of 85%, and (6) a minimum of 6 mm of restorative space and ≥ 10 mm of alveolar bone height without impingement on adjacent vital structures. Exclusion criteria consisted of: (1) individuals with a history of IV bisphosphonate use or head & neck radiation, (2) uncontrolled diabetes HBA1C > 7.0, (3) pregnancy or intent to become pregnant during the course of the study, (4) bone augmentation or extraction at surgical site within the 6 months of enrollment in the study, (5) current smoker of greater 10 cigarettes per day, (6) hard/soft tissue grafting required at the time of implant placement to augment stability, and (7) systemic illnesses that may alter wound healing.

2.2 Pre-Surgical protocol

Twenty-one subjects (22 implants) met the criteria for inclusion in this study. A limited medical and periodontal evaluation was completed, and a periodontal diagnosis of partial edentulism was made for all enrolled subjects. Oral hygiene was recorded using the Modified O' Leary plaque index, and a prophylaxis was provided as needed. At the pre-surgical appointment, a small-field 40x40 mm CBCT (J.Morita Accuitomo 170, Japan) and digital model of the surgical site was made. After merging the data from model with the subject's CBCT image, the implant(s) were digitally planned using implant planning software (BlueSky Bio, Libertyville, IL). The DICOMS from this merge were forwarded to the stereolithography laboratory, where a customized, acrylic, tooth-borne, surgical stent was fabricated for each subject.

For standardization purposes, only two-pieced tapered implants with a Ti-Unite surface and conical connection (NobelReplace, Nobel Biocare, Switzerland) were utilized in this study. All implants were placed per the manufacturer's protocol. To increase the applicability of our results, 5 calibrated providers in the 59th MDW Periodontics clinic placed the implants, but only one designated researcher collected the clinical measurements.

2.3 Surgical Protocol

On the day of surgery, after profound local anesthesia was achieved, a mucoperiosteal flap was reflected past the alveolar crest and the custom surgical guide was seated intraorally. As part of the initial osteotomy, a trephine drill with a 2 mm internal and 3 mm external diameter (Salvin Dental Specialties Inc, Charlotte, NC) was used to obtain a bone-tissue core sample, 4 mm in length, from the implant site. Once removed, the apical portion of the specimen was marked with India ink, stored in 10% neutral buffered formalin solution for 72 hours and submitted for micro-CT and histological analysis. The preparation of the osteotomy was then continued, and the implant was placed into mature bone. One IT and three ISQ measurements (Osstell, Sweeden) were made immediately following placement. If adequate primary stability was achieved, (denoted by an IT value of 35 N cm or greater and a mean ISQ value of 55) only then a healing abutment was placed. The range of ISQ measurements was between 1 and 100, whereby 1 and 100 represented the minimum and maximum readout from the ISQ device. A single ISQ device was used throughout this study. If adequate primary implant stability was not achieved, subjects were immediately disenrolled from the study and their implants were submerged for healing and restored via the conventional loading protocol.

A regular platform, healing abutment (Nobel Biocare Conical Connection, Switzerland) was seated on each implant that continued to meet criteria, and the gingival flaps were replaced to their original position using 4-0 Monocryl interrupted sutures. Primary closure of all surgical sites was achieved. A standardized periapical radiograph of each implant was made using the long cone parallel technique. Baseline marginal bone levels were assessed, utilizing two known radiographic landmarks on the implant (platform and the most coronal bone-to-implant contact) as reference points. All subjects received verbal and written post-surgical instructions. Additionally, all subjects were prescribed a 5-day course of 500 mg amoxicillin for which they took three times a day and 15 mL of 0.12% chlorhexidine gluconate rinse, which was used twice daily. Post-operative pain was managed with over-the-counter, non-steroidal, anti-inflammatory drugs as needed. Following surgery, the bone-tissue core samples were submitted for micro-CT and histomorphometric analyses.

In addition to routine post-operative visits, including suture removal at day 10, subjects were required to return to the clinic at T1, T2 and T3 for follow-up appointments (see Figure 2 for study timeline). At all post-operative appointments, healing abutments were removed, and three ISQ measurements were made. The mean ISQ value from each time point was recorded. Additionally, at T1, early osseointegration was assessed via a percussion test, a periapical radiograph, three ISQ measurements and a Reverse Torque (RT) test of 20 N cm. If the implant met all of the criteria for early osseointegration outlined by the study (a negative response to percussion, negative reverse torque test, and crestal bone loss < 0.2 mm) a final abutment (Snappy abutment, Nobel Biocare, Switzerland) was seated. The implants were temporized and loaded into functional occlusion, with forces directed axially to the implant. To prevent occlusal overload, a minimum of three contact points were required on the implant restoration [6]. Custom acrylic occlusal devices were delivered to all subjects after occlusal loading was achieved. A final periapical radiograph was made. Post-therapy periodontal charting accomplished at T3.

2.4 Micro-CT and Histologic processing

At the conclusion of surgery, all bone biopsies were characterized non-destructively using a micro-CT (Skyscan 1172, Bruker, Billerica, MA). Prior to image acquisition, a flat field correction was performed. Filtration of the polychromatic x-ray beam was done with a 0.5 aluminum filter. Each biopsy specimen was scanned 180 degrees with a 0.4 degree rotational increment per frame using a source voltage and current of 55 kV and 181 μA, respectively. At each rotational degree, three scans were captured and averaged to give one projected frame. A total of 510 projections per specimen were acquired. These projected scans were then reconstructed into a three-dimensional volume with a voxel size of 9.83 μm and 2000 x 1048 pixels per slice, using a customized Feldkamp algorithm (NRecon v-1.7.4.6, Bruker, Billerica, MA). See Figure 1. Image segmentation and analysis were performed using a proprietary software (CTAn v-1.18.9.0+, Bruker, Billerica, MA). Percent bone volume (% BV = BV/TV) value was computed per specimen using bone volume (BV) divided by total tissue volume (TV) per specimen obtained from CTAn, for 21 specimens.

Following completion of micro-CT analysis, specimens were secured into paraffin wax, and the samples were sliced longitudinally, in 5 μm thick slices. Sections were then stained with Hematoxylin Eosin (H&E) for histologic evaluation by a board-certified Oral Pathologist. The highest quality slices from each bone-tissue core sample were selected for histomorphometric analysis. Each specimen was measured in length and width, by a single examiner under light microscopy at 4X to 40X. The amount of mineralized tissue was then measured in the same manner (Figure 1), with mineralized tissue identified via the presence of osetocytes. The amount of marrow/non-calcified tissue present was determined to be the difference between the two aforementioned measurements, which was then converted into a percentage.

2.5 Statistical analyses

JMP software (SAS Institute Inc., Cary, NC) was employed for the statistical analysis of this study. The incidence of successfully osseointegrated, functional implants at T3 was calculated. A repeated measures analysis of variance (ANOVA) test with Tukey post hoc ($\alpha = 0.05$) was completed to determine the statistical significance of the changes among T1, T2 and T3. Bivariate regression was applied to correlate between ISQ and % BV [%], obtained from micro-CT, from which % BV value per ISQ measurement was calculated based on bivariate linear regression and plotted against post-operatively follow-up time. % BV as a function of follow-up time was fitted with an exponential curve. Descriptive statistics were utilized to analyze the clinical and radiographic parameters in question for an assessment of prognostic value.

3. RESULTS:

Twenty-one subjects were enrolled in the study, 13 males and 8 females, with an average age of 62 years (range 25-85). None of the subjects were lost or withdrawn from the study during the T1 and T2 follow-up periods. Only three subjects indicated they had a history of smoking, and two patients reported being type 2 diabetics (most recent HbA1C < 7%). Twenty-two implants were placed and twenty-two bone-tissue core samples were collected.

Figure 3 depicts that ISQ is linearly correlated with % BV ($R^2 = 0.8$). The high coefficient of determination demonstrates the clinical relevance of ISQ values with % BV and thereby indirectly related to implant osseointegration or stability. Additionally, the gold standard, histological analysis was used to confirm a 1:1 relationship between ISQ and % BV. Both micro-CT and histologic analysis showed that the % BV in the bone-tissue core samples ranged from 29% - 82%. Hence, we were able to convert ISQ to % BV values. The % BV was computed by solving x using the linear regression equation, $y = 0.37\,x + 45.49$, where x and y are % BV and ISQ respectively. For example, the mean ISQ value of all implants at T0 was 67 ± 6, which equated to a % BV of 58 ± 13. Based on the ISQ and % BV correlation, we then plotted % BV as a function of post-operatively follow-up times. See Figure 4. At T3, the incidence of early implant osseointegration was determined to be 95% [(21/22) * 100]. As the exponential curve passes beyond T3, the regression line gradually ascends to its asymptotic region, reflecting the anticipated secondary stability of the implants throughout the course of this study. Here, this study defines secondary implant stability as an integral response between implant and its surrounding tissues, resulting in stability after subsequent bone regeneration, remodeling, and osseointegration that was achieved by primary implant stability. Furthermore, the data from this graph indicate the difference in measurements between T0 and T1 was the only timepoint at which the % BV difference was statistically significant ($p < 0.0001$).

Figure 6 shows comparison of changes in ISQ scores amongst initial (T0), 2 months (T1), 3 months (T2) and 6 months (T3) timepoints for all study subjects. The dotted gray and blue lines are visual guides that outline ISQ values for T0 and T3 as the lower and upper bounds respectively. Approximately 82% of patients have ISQ values fell within these bounds. In other words, twenty of the well-integrated implants showed higher ISQ values at the conclusion of the study (T3), than they did at T0. Only one of the well-integrated implants, with an initial ISQ of 80, did not show an increase in ISQ values over the course of the study. This demonstrates the greatest amount of healing occurred at the first recall (T1), whereby ISQ scores collected at T1 as a prognostic factor rival those values collected at T3 more so than at T0. Only one implant was lost as a result of failure to achieve early osseointegration. The one, non-integrated implant was identified at T1 by the patient's symptoms, a positive RTT, a positive PT and evidence of a circumferential radiolucency around the implant on the periapical radiograph.

4. DISCUSSION:

Based on our data, our null hypothesis was rejected. ISQ may be considered as a better indirect indicator to determine the timeframe for practical implant loading than parameters such as IT, RTT, and PT. Furthermore, Figure 4 have demonstrated that there was no difference in implant stability and osseointegration (% BV) between implants loaded under the conventional, three-months protocol and early implant loading at two months.

Loading an implant is a game of biology, and dentists are merely the mechanics. Today, it is understood that bone is a very dynamic tissue and its reaction to the surgical placement of an implant is variable among individuals. Subsequent to implant placement, proteins, blood, immune cells, and osteoprogenitor cells interact with the biomaterial on the surface of the implant, at which point fibroblast like osteoprogenitor cells differentiate into osteoblasts and start to secrete woven bone that grows toward the implant surface. As healing continues, bone remodeling occurs and woven bone is replaced by lamellar bone. This wound healing process leads to osseointegration at the bone-implant interface and is largely dependent on the genetic expression of several factors such as osteocalcin, osteoprotegerin, and transforming growth factor β [13]. Interestingly, Wilderman et al. reported that peak osteoblastic activity occurs between three to five weeks after tissue trauma, with little to no osteoblastic activity occurring at two and three months post-operatively [14]. This signifies, from a biological perspective, that early implant loading at two months is a viable treatment option.

Evolving concurrently with this knowledge of the osteogenic response are the biomechanical properties of implants, most notably, implant surface topography. Surface roughness on a microscopic and submicroscopic level, is one of the most significant advances that has been made since the 1970's and is one of the most critical factors related to osseointegration. It has been theorized that implants with moderately rough surfaces are capable of accelerating the rate and improving the quality of osseointegration by increasing the surface area available for fibrin attachment and enhancing the osteogenic response of the host bone via the proliferation and differentiation of osteoblastic cells. There is a direct, positive relationship between bone-to-implant contact and implant surface roughness, which in turn, provides an opportunity to accelerate treatment and increase efficiency, predictability and patient satisfaction. This study utilized implants with an anodized, porous, moderately rough surface (NobelReplace, Nobel Biocare) which was electrochemically modified to increase the thickness of the titanium dioxide layer. With the enhancement of the physical characteristics to the TiUnite surface, which increased its pore size by 20%, this allows an improved rate of osseointegration towards the implant, and quicker healing via contact osteogenesis. While it is possible that the implant surface utilized in this study led to more rapid osseointegration, the present results are not merely the result of the selected implant surface characteristics. Similar results were seen in a study by Lethaus et al., where early loading at 6 weeks showed successful and predictable osseointegration of implants with the Sandblasted and Acid-Etched (SLA) surface [15].

Analysis of primary outcomes of this study revealed the incidence of osseointegration of early-loaded implants was 95%, which compares well with the reported 98% incidence of conventionally loaded implants [16]. Furthermore, from our ISQ data, it was determined that the majority of subjects (82%) exhibited the greatest amount of healing within the first 2-months after implant placement, with the 2-months, 3-months, and 6-months ISQ values being nearly the same. These results indicate that the closer the baseline ISQ values are to 55, the higher the bone growth value is expected to be over the first two months. This is consistent with the findings from Rodrigo et al., who found that ISQ values < 60 at the time of restoration was predictive of implant failure [17]. On the other hand, implants with an incredibly high ISQ value at the time of insertion, closer to 80, showed the least amount of bone growth. In both of these situations, there was a plateau in implant stability after 2 months, indicating the peri-implant bone was dense and uniform at this point. This is in accordance with Berglundh's osseointegration timeline [2]. Therefore, for those implants that are well healed in the posterior mandible, the results of the present study indicate that one would not expect to see a downward trajectory in ISQ values at or after 2 months. This exponential and asymptotic pattern of bone growth seen in this study (Figure 3) is consistent with the literature on implant wound healing and implant stability.

On the contrary, there was one subject whose implant had failed to achieve early osseointegration. It is important to note that this implant met minimum criteria for inclusion in this study (Figure 4). Additionally, the mean ISQ value for this implant at T2 was 54 ± 2, which showed a downward trajectory from baseline. This is consistent with the RFA manufacturer's (Osstell) information for "risky behavior" even though the failed implant had an adequate IT of 35 N cm. It is also important to note that despite a low positive predictive value, IT was determined to be prognostic only when used as a dichotomous measure (above or below 35 N cm) and in conjunction with ISQ. For instance, if predicting osseointegration solely on IT, the present data suggest that with a total of 13 patients, who exhibited a high initial torque (> 40 N cm), 9 patients (69%) were identified as having a true-positive connection with high % BV, whereas 4 patients (31%) were identified as having a false-positive connection with high % BV (Table 1A). The % BV for the 4 patients were actually lowered than 56%.

Ultimately, IT only assesses the strength of the bone to implant contact (BIC) at the time of placement and does not predict the subsequent bone remodeling that will occur. Relying on IT alone is problematic for several reasons. One, primary stability is more dependent on the healing and adaptation of the host tissues after implantation and less on whether implants are placed with high or low initial insertion torque. Two, it is still unclear about whether high IT may introduce high degree of stresses and strains in the supporting bone, leading to extensive bone remodeling and in the disruption of "normal" healing. It may be true that tactile information furnished by the first surgical "twist" drill can provide vital clue about implant stability, but this tactile sensation can also be duplicated by inserting an implant that is larger than its osteotomy prep site. This macro-geometric implant in an undersized osteotomy preparation provides a "press-fit" situation in which stress and strain can easily transmit into the supporting tissues [18]. Therefore, by modifying the surgical drilling protocol, the IT can be subjectively altered to present better "stability" at the time of initial implantation. Additionally, most implant systems utilized today do not contain a calibrated torque ratchet with an inbuilt electronic torque control setting. This is why many surgeons opt to verify their IT with a manual toggle-type wrench. Nonetheless, according to a recent study, the manual wrench has been shown to be largely affected by aging – with loss of accuracy of the spring mechanism occurring after multiple uses and cleaning procedures [17]. Some reported that the corrosion of the spring could impart torque values up to 455% of the desired value [17]. This makes it difficult to know exactly how much torque an implant is receiving at the time of insertion. Therefore, it is more ideal to combine IT with other clinical and morphometric parameters to aid as a longitudinal measure of implant stability.

Despite a lack of research, recent advances in implant dentistry, in conjunction with the inception of personalized medicine, have made early implant loading an art supported by clinical practice. When considering implant therapy there is infinite variability in surgical circumstances that can arise, each lending themselves more suitable for a different loading timeline. Therefore, it is in good agreement that the conventional loading guideline serves as a one-size fits all protocol that may unnecessarily prolong treatment times and may not be applicable to all patients and all clinical scenarios. As dental professionals, better outcomes for patients receiving dental implants remains the constant goal. To meet this goal, implant dentistry has evolved from an experimental treatment in animals to a highly predictable option to replace missing teeth in humans. With emerging technologies and a better understanding of the osteogenic response, clinicians are equipped to make proper, individualized decisions for each of their patients, giving birth to the concept of precision dental care. Precision dental care, a relatively new practice, involves the integration of a patient's medical history, familial risk factors, clinical presentation, and social and environmental factors into their dental treatment [14]. Accounting for variability, patients can then be stratified into phenotypic groups. For instance, using the results of the current study, individuals can be stratified by loading time in the posterior mandible based on their initial ISQ measurements [18]. The data from the current study also confirms osseointegration can be predicted on an individual basis, via ISQ. However, to most effectively use ISQ to stratify patients, further studies including more implants with longer observation periods are needed to avoid the influence of confounding factors such as the differences between implant systems and surface characteristics. Additionally, there is one large difference that exists between individuals and implant sites: the quality of bone. According to Lekholm and Zarb, the posterior mandible consists of mostly Type II bone, suggesting these quadrants of the mouth display excellent vascularity and healing capacity [19]. Therefore, the results of this study are not applicable to implants placed in other quadrants of the mouth. Future areas of investigation include correlating the results of the current study with an individual's WNT signaling pathway. This data will hopefully arm clinicians with a way to analyze a patient's blood profile during implant surgery to more accurately predict the course of osseointegration.

The differences that exist between individuals and the recent technological advances in the field of implantology provide the rationale for the reconsideration of individualized, early implant loading. From a patient centered outcomes aspect, early loading meets patient expectations for simple and realistic time intervals for treatment. However, to ensure early success, it is important to account for factors associated with occlusal overload such as large cantilevers, parafunctional habits, and poor distribution of forces [2]. This is critical as mechanical overload can lead to marginal bone loss and prosthesis failure, and can even disrupt oseeointegration of an implant during healing phase.

5. CONCLUSION:

To mitigate the detrimental effects on the dento-alveolar complex and the systemic health of an individual, it is essential that expediency be at the forefront of treatment planning when restoring edentulous sites. Therefore, it is important for clinicians to assess each case based on a benefit/risk ratio for early loading protocols. Recognition and utilization of the inherent biological differences between individuals minimizes the amount of idle time between implant placement and restoration, considerably reducing treatment times. The results from this study indicate the majority of patients will exhibit the greatest amount of osseous healing in the first 2-months period after implant placement. Furthermore, the present data suggests that patients with an initial ISQ value of greater than 80 will tend to show the least amount of ISQ value improvement over time. This is because, generally, bone tends to grow exponentially and asymptotically, approaching a maximum value at which point it enters a state of quiescence at 2 months. As a result, early implant loading can be predictably achieved in the posterior mandible via ISQ stratification. These results provide clinicians with a systematic approach for delivering care, optimal for each patient, allowing them to serve their patients to the highest standard of care.

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