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Chapter - 6

Applications of Narrow Diameter Implants in Removable Prosthodontics

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Chapter - 6

Applications of Narrow Diameter Implants in Removable Prosthodontics

Nesreen El Mekawy and Christine Raouf Micheal Ibrahim

Abstract

Narrow dental implants can provide support for stabilization of a removable full and partial dentures and can be installed with a minimally invasive surgery thus it is a recommended for the patients who are compromised condition. In addition narrow dental implants can be used in cases where there may be anatomical, medical or financial constraints.

Keywords: narrow dental implants, removable prosthodontics, overdentures

Introduction

Now days, dental practitioners have a major defiance in the management of the totally and partially edentulous patients. The conventional treatment modality for these patients was the construction of complete denture. Unfortunates; often these patients were unsatisfied with this line of treatment because of the lack of retention, support and stability of the complete denture leading to discomfort, and diminish of the patients function.

Utilization of dental implants in restoring the missing teeth started at 1970's. In this treatment concept the dental implants were used to inspire the implant overdenture treatment modality instead of the well-known tooth overdenture. As the dental implant was used instead of the missed teeth roots, that connected to the denture by an attachments which is an optional methods in the tooth overdenture but with the implant overdenture the utilization of the attachments became a mandatory way to improve the retention, support and stability of the prosthesis.

Historically, the mainly documented and used dental implants, were those with diameters between 3.75mm and 4.1mm. Those dental implants were employed for numerous clinical situations and provide great scientifically success particularly in the long term treatment ^[1, 2]. These type of dental implants are widely regarded as standard diameter of implants. One

of standard diameter implant disadvantage is the fact that, in clinical use, the available horizontal crestal dimensions of the alveolar ridge as well as the spaces between adjacent teeth and dental implants are sometimes too small [3].

Numerous authors advised that at least 1mm of residual alveolar bone should be present facially and lingually around the implant in order to improve implant success, which consequently requires at least 6 mm width of residual alveolar bone for utilization standard diameter implants. Furthermore, based on available studies a 3 mm inter-implant distance seems to be adequate and beneficial for papillary fill [4, 5]. Thence; the following question has been raised, if optimal implant diameter might be narrower than the “standard diameter” for many clinical indications? [3]

In these times; utilization of dental implants with a diameter less than the conventional one has increased. These were firstly used for temporary retention of the interim prosthesis and for orthodontic anchorage. Nowadays there is an increased use of them for prosthesis stabilization. Dental implants with diameters between 3.0 mm to less than 3.75mm ($3.0 \text{ mm} \leq \text{diameter} < 3.75\text{mm}$) have been considered to be narrow diameter implants (NDIs).

The Glossary of oral and maxillofacial implants define Narrow Diameter Implants as “dental implants that have diameters between 2.2 mm and 3mm and often the implant surface is enhanced to help promote integration) [6].

Indications of narrow diameter implants

NDIs are used in clinical situations including narrow bony ridges as an alternative to bone augmentation procedures and in sites with reduced interdental gap width. This might help especially elderly patients or patients with general medical risk factors since there is a reduced surgical invasiveness. In addition, it is not a time-consuming treatment protocol with less complication and post-operative pain. The most important indication is their use in small inter dental or inter-implant gap, which usually found in premolar or incisor regions. Therefore, the employment of NDI ($< 3.5\text{mm}$) has broaden the treatment spectrum [3].

When you choose to provide your patient with NDIs treatment modality, you will increase the range of treatments available for patients. Some clinicians are still unsure about the long-term viability of NDIs but a recent 14-year follow up study evaluating bone loss, peri-implant bone remodeling, and esthetic outcomes reported no implant failures or prosthetic complications. Equally as importantly, patients were found to be very

satisfied with their treatment ^[7]. When selecting patients to enrolled for this treatment, one of the paramount consideration is the thickness of the surrounding soft tissue. If the soft tissue is thicker than approximately 2 mm, thus; it may need to be reduced, this may be done before surgery or at the time of implant placement surgery ^[8].

Classification

The previous classification of NDIs by Klein *et al.* ⁽³⁾ was the following:

Category 1: < 3mm (mini implants)

Category 2: 3mm to 3.25mm (single tooth indication)

Category 3: 3.30mm to 3.50mm (broader indications)

Recently; a new classification have been developed in the field of NDIs to modify this classification, it is proposed by Jung *et al.* ^[9]

Category 1: Implants with a diameter of <2.5 mm (“Mini-implants”)

Category 2: Implants with a diameter of 2.5 mm to <3.3 mm

Category 3: Implants with a diameter of 3.3 mm to 3.5 mm

Now days, most implants of <2.5 mm diameter are one-piece implants. One-piece implants with a diameter of >3.0 mm are rarely described.

Treatment planning when using NDIs

One thing you will need to decide is whether to use a one-piece implants or two-piece NDIs.

One-piece implants

Advantage of utilizing one-piece NDIs is the elimination of any micro-gap between the abutment and the implant. ⁽¹⁰⁾ While; the disadvantage of using a one-piece NDIs is that it requires ideal placement, as angle correction abutments cannot be used and, one-piece NDIs must remain out of occlusion for successful osseointegration ^[11].

Ideally, NDIs should be installed as parallel as possible to allow reducing the technical problems of the prosthesis insertion and, the risk of implant failure. When; one-piece implants are utilized for a full-arch restoration, the implants should be splinted ^[12].

If less surface area will contact with the bone, thus loading forces need to be considered. The existing bone height and width influence the forces placed on a dental implant. As lower bone height can negatively affect this. ^[13] When it's necessary to reduce the forces on implants, the options are

increasing the number of implants, using longer implants, or choosing implants with increased surface texture.

When the treatment is correctly planned, the NDI's are placed and loaded properly, thus; NDIs can produce a remarkable treatment modality for patients who may not be suitable for dental implants. Whilst; they may not substitute regular diameter implants, NDIs can be a valuable treatment for patients.

The potential advantages of using NDIs. ^[14]

NDI should be considered when:

- 1) It is important to ensure maintenance of adequate tooth-implant and implant-implant distances in sites with reduced mesio-distal width
- 2) It can be considered to reduce the need or complexity of lateral bone augmentation procedures to reduce morbidity
- 3) It may allow simultaneous rather than staged bone augmentation procedures
- 4) It provide increased prosthetic flexibility in certain clinical situations

The potential disadvantages of using NDIs ^[14]

Various disadvantages can be considered as Biological or Mechanical disadvantages.

First biological disadvantages

The using of one-piece NDIs with ball attachments might be difficult to manage at the onset of dependency. In addition: the use of NDI may compromise optimal prosthetic designs which allows the maintenance of peri-implant tissue health.

Second mechanical disadvantages

The reducing of implant diameter brings increasing the risk of implant or component fracture. Additionally: Caution is recommended for the use of NDIs in patients with parafunctional habits and malocclusions.

The indications of each class of NDIs ^[14]

NDIs Category 1 can be indicated for

- 1) Support of definitive complete mandibular overdentures
- 2) Support of interim prostheses, both fixed and removable

NDIs Category 2 can be indicated for

- 1) Support of definitive complete mandibular overdentures
- 2) Support of single tooth replacement in the anterior zone with narrow interdental width (maxillary lateral incisors and single mandibular incisors)

NDIs Category 3 can be indicated for

- 1) Support of definitive complete overdentures; Support of single tooth replacement in sites with reduced interdental and/or buccal-lingual width; Support of multiple unit restorations

The use of narrow diameter implants in complete edentulous patients

The use of NDIs with mandibular overdentures

For edentulous patients; oral rehabilitation with two-implant retained overdentures become the standard option as they reduced costs with improved the quality of life ^[15]. In order to increase ridge width in case of reduced alveolar ridge buccolingual width in the canine regions, A guided bone regeneration, with autogenous onlay graft and horizontal distraction osteogenesis may be used ^[16, 17]. Other alternative treatment options include the ridge expansion ^[18] and the use of small diameter or mini dental implants ^[19], which reduce the morbidity and costs of bone grafting procedures especially for debilitated geriatric patients ^[20].

In a study by Pareoteasa *et al.* ^[21] discussed the principles of overdenture on one-piece narrow dental implants in cases with severely ridge resorption (flat ridge) and narrow ridge cases. The study stated that the number of narrow dental implants to be used, which vary, usually 2 to 4 implants being sufficient. A higher number being chosen in younger patients (under 60 years), in those with a harder food diet, bruxism and patients with more obvious tendency to ridge resorption.

According to Aunmeuntong and colleagues ^[22], the cumulative survival rates of two immediate narrow dental implants-retained mandibular overdentures and of four immediate mini dental implants-retained mandibular overdentures were 100% in one-year study. In clinical study result there were insignificant differences in patient satisfaction and marginal bone loss between two narrow dental implants-retained mandibular overdentures and four narrow dental implants-retained mandibular overdentures.

Sites for narrow dental implants NDIs usually are in the inter-foraminal area, upon considering the bone density, width and height, and the prosthetic needs (a surgical template can be used for a more accurate localization of implant placement site). Surgical techniques of implant placement, by the usage of a flap technique to accurately evaluate bone width through direct assessment, or flap-less technique to reduce invasiveness of the surgical procedure [23].

Loading protocols for NDIs can be either an immediate loading protocol (i.e., immediate fixation of the metal rings in the overdenture base) or progressive loading protocol (i.e., soft lining materials were used as soft matrices during the Osseointegration period). Utilization of immediate loading protocol the force distribution has an important part in the success of the treatment by implant-retained overdenture overloading from occlusal force around dental implants should be avoided. Thus, for implant treatment success occlusal analysis becomes an important phase [24].

For reduced implants diameter; the time of loading is still of interest, especially. Immediately loaded implants have been associated with many implant-related complications and poor survival rates [25, 26]. Immediate loading of inter for animal implants splinted by a bar system and overdenture can be used successfully with good survival rate [27, 28].

The placement of NDIs in the posterior mandible of 2.75 mm diameter implants, as well as 3.25 mm ones, must always be splinted with a bridge, placing one implant for each missing tooth. The placement of a NDI implant in a single molar crown is not recommended. Splinting multiple implants has been reported to minimize the lateral force on the prosthesis, to enhance force distribution, and to reduce the stress on the implants. Thus, splinting of NDI implants would protect the implants from excessive loading and prevent implant/abutment screw fracture. Necessary measures should be taken to minimize off-axis forces like reduction in occlusal table and cusp inclines [29].

This was in agree with a more recent randomized clinical study which was conducted to compare immediate and early loading protocols for mandibular overdentures with two- splinted narrow diameter. The study resulted the following, in the 24 implants of the immediate loading group, the mean bone level change from surgery/loading to the first- year evaluation was 0.32 ± 0.80 mm ($p = .066$). Regarding the early group (22 implants), the mean bone level change from loading to 1 year was 0.34 ± 0.69 mm ($p = .048$). After 1 year, no differences could be detected between

groups ($p = .91$) with a mean difference of 0.02 mm (95% CI: [-0.42, 0.47]). The mean implant survival and success rates were 100% for both groups' implants in thin, non- augmented residual ridge situations ^[30].

In addition to splinting the NDIs, another study using un-splinted NDIs retaining mandibular overdenture and loaded immediately revealed that immediate loading of reduced diameter implants supporting overdentures with locator-analog attachments resulted in high implant survival rate, a low incidence of prosthetic complications, good oral hygiene, and improved subjective perception after 12 months. It might be a promising treatment option, especially for elderly patients with a narrow mandibular ridge. For all these factors, after 1 year of observation there seems to be no difference between support by use of 2 or 4 reduced-diameter implants ^[31].

Various attachment types, such as Locator, ball, magnetic, and OT Equator attachments system, have been utilized in implant-retained overdentures. The OT Equator attachment system is recently launched narrow dental implant attachment, which has smaller size than those of other attachment systems, and have evidence of fewer prosthetic complications than has the ball attachment. ⁽³²⁾ Types of attachment systems, which are available for one-piece narrow implants are usually O-Ring, some other variants being available (e. g., Locator, LODI implant system, Zest Anchors; magnet, Magfit) ^[33, 34].

The NDIs retained mandibular overdenture design should aim to ensure adequate support, retention and stability, a complete coverage of the support area, in correspondence with the anatomical and functional borders. It should not exert pressure on the dental implants, when they are used only to increase retention, not for support. It should be made at correct inter-maxillary relationship, providing a stable occlusion. In addition, previously made complete dentures can be either kept and transformed into overdentures when considered satisfactory to promote a faster adjustment with the new treatment especially in the elderly who have difficulty adapting to change. Also, complete overdentures can be preserved as interim prosthesis during the healing phase when considered unsatisfactory, but not having severe deficiencies that may be risk factors for implant failure or replaced before implant placement ^[21].

Narrow dental implant treatment conduct with flat alveolar ridge patients

These patients usually have wider alveolar ridges that allow placement of larger diameter dental implants, but have a reduced bone height, which associates the need of use of shorter dental implants ^[35].

Clinical problems related to this group of patients

They are usually old patients, seeking for improving denture retention by minimally invasive surgery and, moderate costs. They complaints of poor denture stability and retention and sometimes pain under the dentures. Many of them are long-time mandibular denture wearers, some of them having teeth or fixed conventional or implant prosthesis in the maxilla (these being risk factors for severe ridge resorption) ^[36].

They often eat soft diet, because of the masticatory deficiencies due to the ill-fitting dentures. The attached mucosa thickness is reduced related to the long period of denture wearing so, the basal tissues becoming painful under the pressure exerted by the denture. Furthermore; changes of soft peripheral tissue that increase treatment difficulty, such as: moving of muscle and ligaments attachments to be close to the crest of the ridge; herniation of sublingual glands; tongue hyperactivity; posterior position of tongue during rest position; hypertonia and shortening of the lower lip orbicularis oris muscle that enhances mandibular denture instability ^[37].

These patients may have an abnormal sagittal and horizontal ridge relationships that can be related to factors such as the skeletal class, the pattern of the bone resorption of the jaws (centripetal in the maxilla, respectively centrifugal in the mandible) and the anterior hyperfunction syndrome (combination syndrome) which contribute to the facial appearance known as pseudo-skeletal class III facial appearance or the old man's prognathism ^[38].

These patients generally have oral conditions unfavorable to obtain a good denture stability, support and retention, with a high degree of treatment difficulty according to Prosthodontics Diagnostic Index (PDI) classification System of American College of Prosthodontics (ACP) ^[39]. The usage of dental implants being considered appropriate in order to ensure an adequate functionality with the prosthesis.

The treatment planning in these patients by NDIs overdenture, without bone augmentation procedures usually has the following pattern

To treat a patient with flat ridge a number between 2 and 4 narrow dental implants is usually sufficient with shorter dental implants of less than 12 mm or 10 mm are frequently needed ^[40]. The interforaminal region is the most favorable site. In cases with severe ridge resorption, sometimes-adequate bone quantity is found only nearby the mental symphysis, thus, in these cases without bone augmentation the implant number being limited to 2 implants, placed in the anterior part of the mandible ^[41]. Dental implants

can be usually placed by a flapless technique, generally; the bone density is assessed as being favorable concerning a good primary stability. In case of, immediate implant loading, the vertical prosthetic space is generally sufficient for O-Ring attachment system ^[42].

Narrow dental implant treatment conduct with narrow alveolar ridge patients

These patients usually have unfavorable conditions for conventional denture construction and, dental implant placement, due to the reduced width of alveolar bone and sometimes the sharp ridge crest, covered by a painful mucosa. So that; narrow dental implants are indicated especially in cases with narrow-ridges, considering their diameter is well suited to bone width (at least 4 mm width) ^[43]. Narrow alveolar ridges are encountered more frequently in patients with the following characteristics: have more frequently a class II hypodivergent skeletal pattern, which associates tongue and lip muscle hyperactivity.

They are often recent edentulous patients with low-density bone trabeculae, and first-time denture wearers; present to the dentist usually dissatisfied with denture instability and complaining about pain related to denture pressure. Alveolar ridge morphology is usually high and thin, with a greater depth of the vestibular sulcus. The morphology of the alveolar ridge is characterized by the relatively frequent presence of cortical bone irregularities, such as exostosis, covered by thin mucosa related to pain under conventional dentures. In previous wearers of ill-fitting dentures in which tooth loss is mainly linked to periodontal disease, there was rather often encountered flabby ridges and mucosal hyperplasia ^[38].

Conducting a proper treatment protocol in these patients by narrow dental implant overdenture has usually the following pattern: the number of implants is generally between two and four narrow dental implants. According to bone offer, the degree of overdenture retention needed and number of implants can be increased later. If the clinical situation requires implants usually have higher length, of more than 12 mm or 14 mm; implant diameter is usually smaller, corresponding to ridge width ^[44].

More considerably, the implants are installed by a flap technique, chosen in order to correct bone and mucosa alterations, and to adequately assess bone offer and the limits of implant placement (to prevent cortical perforation). For implant loading, progressive implant loading is usually preferred due to reduced bone density, for which soft silicone or acrylic materials may be used during the osseointegration period for amortization of occlusal forces or peri-implant soft tissue conditioning ^[45].

The healing process is slower compared to the one of the patients with flat ridge considering that in these patients usually a flap technique is used for implant placement. The vertical prosthetic space may be decreased, in relation to the skeletal class; therefore, implants with other type of attachment system (e.g., magnets) can be used.

The risk for a mechanical overdenture fracture is higher because of the reduced width and thickness of overdenture base, especially when there are placed more than two implants. Dental implants are especially beneficial in recent edentulous patients with narrow-ridges, through minimizing the bone resorption, which has the highest rate after tooth loss and is enhanced by ill-fitting dentures ^[46].

The use of NDIs with maxillary overdentures

Patients with conventional maxillary dentures may seek implant treatment to obtain higher retention and comfort gained by the reduction of palatal coverage ^[47]. The reduction of the palatal coverage gives more room for the tongue, exposes additional palatal tissue for better appreciation of food texture ^[48] and provides greater comfort especially for patients with hyperactive gag reflexes or maxillary tori ^[49].

The use of NDI to retain maxillary overdenture is still under clinical investigation various *in vitro* study have been done to examine the retention and stress on the narrow dental implants with maxillary overdenture omitted the palatal coverage (palate-less overdenture). First study ^[47]; was done by using five un- splinted one-piece narrow dental implants that retained palate-less overdenture and it was concluded that the retention is predominate effect by mechanical retention rather than physical factors in retention of mini-dental implant overdenture with and without palatal coverage.

Another study ^[50]; was examined the influence of un- splinted implant number and palatal coverage on retention, cyclic fatigue and denture base deformation of maxillary overdentures supported by five versus seven unsplinted mini implants. It was found that Overdentures with partial palatal coverage and assisted by seven MDIs exhibited comparable retention, cyclic fatigue and induced strain to overdenture with complete palatal coverage assisted by five MDIs.

A study by Elsyad *et al.* ^[51] was conducted to evaluate and compare the level of marginal bone loss around six mini implants used to retain maxillary overdenture with partial or complete palatal coverage. The study concluded that the rehabilitation of the edentulous maxilla with six un-splinted mini implants supported overdenture with partial palatal coverage is not

recommended as for the excessive marginal bone resorption and a higher than expected mini implant failure rate.

A newly systematic review on NDIs survival rate included 15 prospective studies on overdentures and found that NDIs failure rate of 4.9% (69 out of 1412) for the mandible and 31.7% (52 out of 164) for the maxilla. Thus; it was suggested that NDIs supported maxillary overdentures could not yet be recommended due to high failure rates and, limited evidence of study.^[52] Nevertheless, this review conclusions were based upon only three prospective studies which reported that on only 164 maxillary MDIs. Moreover, these studies are in conflict with the treatment standardization. On the other hand, patient-reported outcomes emphasize the improved satisfaction of all patients undergoing this treatment^[23].

A systematic review and meta-analysis on maxillary overdentures retained by implants with regular diameter and placed by classic flap surgery, reported that the overdenture survival rate of 99.5% and implant survival rate of 98.1% in case of six or more regular implants splinted by bar^[53]. However, these losses did not affect the success rate for the overdentures, which was 98.8%. The total failure rate of 17.3% for NDIs placed with a flapless technique. The study may appear unacceptably high as reported by a clinical study by Van Dornee *et al.*^[54] It is indeed 6% higher as compared to four non-splinted conventional implants, but is much better than the 30% failure rate reported in other studies using maxillary NDIs.

Several researchers suggested a minimum of four MDIs to be installed in maxillary arch when partial palatal coverage is planned^[48, 55]. Nonetheless, others claimed a minimum of six MDIs for convenient retention of complete removable maxillary overdentures^[56]. However, Patel^[57] suggested the use of seven un-splinted MDIs with palateless maxillary overdentures as reported in his case report.

For acceptable retention of complete dentures four implants in the mandible and six implants in the maxilla are the minimum number of narrow dental implants required^[58]. The parallelism of narrow dental implants for overdentures generally does not exceed degrees in order to avoid non-seating of the overdenture and to convert the axial loads to off-axial loads by the tilted implant position^[58, 59]. To ensure close parallelism a surgical guide may be needed for narrow-implant placement.

Treatment with narrow dental-implant in the posterior maxilla may not be appropriate due to the loose underlying trabeculation and thin cortical bone (types III to IV) which provides a decreased osseous matrix for

osseointegration ^[60]. Bone types II and I could give long term best results. Moreover, occlusal forces may be a consideration in the treatment planning because it is much greater in the posterior maxilla. The occlusal forces in the anterior are much less, and this area is more conducive for mini-implant use ^[56].

For immediate loading of narrow dental implants at least 11.5 mm implant length could be required for retention of removable complete dentures this is usually based on the experience of the authors ^[61]. However; the length of the implant does not contribute to the stability of the implant as does the implant diameter. Thus, to compensate the small diameter, a longer implant length may introduce additional surface at the implant/bone interface. In patients has little occlusal biting an implant with 10 mm length in type I bone may be acceptable forces ^[56].

The use of narrow diameter implants in partial edentulous patients

A traditional removable partial dentures (RPDs) is an acceptable choice of treatment options which is widely used to rehabilitate the partially edentulous patients. Nevertheless, the propagation of various biomechanical troubles with RPDs is high, ⁽⁶²⁾ often, the utilization of RPDs regularly causing damages of oral tissue. ⁽⁶³⁾ Especially, the occurrence of problems related to retention which has higher incidence in the mandible than in maxilla ^[62].

Also; the rates of retreatment of RPDs are higher in distal extension base in comparison with tooth-supported bases ^[64]. Mandibular class I Kennedy classification RPDs show limiting anatomically supporting area when compared to that of maxilla, and the oral mucosa is vulnerable to loaded occlusal force during function. The horizontal, vertical and torsional forces class I Kennedy classification RPDs tend to move the saddles toward the basal seat tissues and could act as possibly destructive forces on the anterior abutment and residual alveolar ridge. Additionally, mechanical complications may be induced due to bending moments and excessive shear forces on the RPDs ^[65].

In cases of class I Kennedy classification RPDs, implant-assisted removable partial dentures (IARPDs) have been introduced as a cost-effective and minimally invasive treatment to head the associated limitations of traditional RPDs via implant installation ^[66]. IARPD effectively converted a Kennedy I classification into a classification III via a posterior support that changes from oral mucosa to implants ^[67]. Placement of an implant in a distal edentulous ridge reduced bending moments and shear forces on the

partial denture ^[68], dislodgement of distal extension base during function, and stress on soft tissue and the abutment teeth ^[69].

The use of implants with standard diameters (> 3.5 mm) is limited due to bone atrophy after tooth extraction and the resulting narrowing of the alveolar process. Implants with reduced diameters (3-3.5 mm) are not always indicated for single attachment. Finally, augmentative procedures to improve the bone volume are not only associated with risks for patients with systemic diseases, but they are also frequently rejected, particularly by older patients because of the longer treatment duration as well as the greater effort required ^[70].

Narrow dental implants with an even smaller diameter (< 3 mm) are usually one-piece, and therefore, a no-load osseointegration is hardly possible. They are mainly used to stabilize complete dentures by means of ball attachments. For this, 6 NDIs in the upper jaw and 4 NDIs in the lower jaw are recommended ^[52]. The most recent systematic reviews have reported high survival rates ($> 95\%$) after an average period of 3 years and low bone resorption rates (< 1.2 mm) in the edentulous mandible. ⁽⁷¹⁾ Contrary to this, after immediate loading in the edentulous maxilla, the NDIs rate of failure was unacceptably high at 32%. If the bone quality is poor, or more specifically, the insertion torque < 35 Ncm, the dentures should first be hollowed out in the area of the attachments and lined with soft material. This apparently leads to fewer failures ^[72].

For immediate loading and for follow-up checks, reference values as for two-piece standard diameter implants are desirable. Meanwhile, there are now two studies with an observation period of 12 and 6 months, respectively, on the successful application of NDIs for better support of RPDs in the presence of remaining anterior teeth (Kennedy Class I). ^(73, 74) To date, there have only been case reports on the use of NDIs as strategic abutments to improve load distribution and retention under existing RPDs in the conditions of few or unfavorably distributed residual teeth. The results from a prospective, randomized 3-year study on the same topic, where the design has been published so far, are still pending. ^(70,75)

In a four-center randomized controlled clinical trial by Mundt *et al.* ^[70] patients who had RPDs in arches with unfavorable teeth distributions (i.e. no canine or no posterior abutment teeth in one or both arches) received strategic mini implants with ball abutments. One group, mini implants were loaded immediately either by O-rings with metal housings or by soft lining material (if insertion torque was < 35 mm), the other group; mini implants

were loaded conventionally after 4 months. This study recorded that the chewing performance was improved by inserting supplementary mini implants under existing RPD with unfavorable tooth support. This improvement occurred faster by immediate loading than by delayed loading [76].

Biomechanics of Narrow Diameter Dental Implants (NDIs)

Conventionally; narrow-diameter implants (NDIs) usually associated with failure high rates when compared with regular-diameter implants (RDIs) and wide-diameter implants (WDIs), because they produce a more unfavorable peri-implant bone stress distribution [77].

Narrow dental implants are obtainable in different designs, through which the surface area, thread pitch, and length are differ. One of the contributing factor to obtain the success of implantation is implant design [78]. The implant design effect directly on the biomechanics of the peri-implant bone. In theory, by analyzing the strain and stress distribution and magnitude in the bone around the implant when a load is applied on the dental implant. So, it can be determined the saving of the utilization of narrow dental implant. Since experimental or clinical investigation on strain and stress on peri-implant bone is very difficult. Instead, researchers use finite element analysis for this purpose [79].

Hence a study by Hisam *et al.* [79] on narrow dental implant is done to examine the stress induced and the strain on bone around implant when the implant is loaded. The investigations consider the difference in the types of bone (II, III and IV). The variability in induced stress is proposed to be from the difference in the implant surface area. This study adds that lower thread pitch causing the distribution of stress more evenly to the bone around the implant. This is indicated by the wider induced stress region and, the lower maximum stress on cortical bone. In terms of strain, there was little variable between the strains induced by the narrow dental implants with various thread pitches. This little variable in induced strain occurs on both cancellous and cortical bones.

In order to investigate the variable in strain and stress revealed by various bone types (II, III and IV) with the bone implant having 1.0 mm thread pitch. It could be concluded that, if the type changes from bone type II to bone type III, the maximum stress becomes lower but more high stress was distributed in the cortical bone. But, if the bone changes from bone type II to bone type III it causing the higher strain (of more than double) become on the cancellous bone. In case; the type of bone changes from bone type III

to bone type IV, doubled maximum stress was shown, and higher stress was distributed over the cortical bone. In case of cancellous bone, leading to lowering the maximum stress, but increased the strain about three folds when compared to bone type III. Synoptic, the induced strain and stress by the narrow dental implant with three different thread pitches and various types of bone are remain within the safer area of the peri-implant bone ^[80].

Comparing a study on mini implants with former study by the same authors on regular sized implant ^[81, 82], it is exciting to found that the stress induced and strain around the peri-implant bone were lower for the former one. This difference may be due to numerous factors, such as, the thread pitch, the overall surface area, and, the differences in geometry shape of the implant's neck. Another observe is that when taking into consideration the maximum yield stress and strain of cancellous and cortical bones, So, the induced stress and strain by the mini dental implant with three various thread pitches is safer or under the allowable stress and strain ^[81].

The benefit of splinting NDIs

The expression splinting (or stabilization) pointed to binding implants or teeth together to increase the stability of the structure as a whole. The reasoning behind the implants splinting was achievement better distribution of off-axial forces and increase the total area receiving the load. Some authors have found that splinting implicates biomechanical benefits and leads to sharing of load ^[83]. However, studies on the clinical use of splinted NDIs is still limited. Likewise, FEA studies were concentrated on single-unit restorations or fixed prostheses supported by multiple SDIs, but still there is a shortage of FEA-based searches assessing multiple NDIs supported prostheses. However, splinted mini-implants (1.8 mm in diameter) was compared with single mini-implants clinically revealed similar amount of bone loss ^[84], implants splinting diminished the tensile stress in the posterior area of short fixed bridges ^[85].

It is well known that the load sharing effect associated with prostheses supported by multiple implants (also called splinted prostheses) affords mechanical benefits. A recent study by Valera-Jiménez *et al.* ^[77] involves finite element analysis (FEA) to determine whether the risks linked to NDIs could be mitigated by the mechanical advantages afforded by the splinting concept.

The mechanical advantages of the splinting concept were assured: the excess load in peri-implant tissues around NDIs splinted by the three-unit bridge was reduced significantly when compared with the non-splinted case

and, importantly, evidenced that it is smaller than the load around non-splinted implants with a regular diameter (RDIs). However, splinted NDIs supporting the all-on-four denture causing the highest risk of overloading present in the study, because of the increasing in compressive stress generated around the tilted implant when loading the cantilevered molar ^[77].

Appropriately, the concept of splinting when applied to NDIs may be another possibility to the utilization of the regular implants or the alveolar bone augmentation procedures, to obtain a prosthetic solution that was traditionally avoided the implants using. Indeed, the sharing of load influence is due to the attitude which was presented as a means of recompense for the over-loading and, resorption risks that is associated with NDIs. Nevertheless, although this reasoning appear to be adequate for simple design like the three-unit bridge analyzed. But, particular attention must be taken if the implants support cantilever dentures or would be installed in a tilted situation, like in the condition of the posterior implants in the all-on-four concept ^[29].

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