Narrow Dental Implants in Posterior Regions of Upper and Lower Jaws

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On posterior part of the jaw the gold standard is to place a regular diameter implant which is ≥ 3.75 mm that can replace the missing posterior teeth. But due to horizontal bone resorption after extraction mostly with cases treated without ridge preservation procedures during extraction, using regular diameter implants are not possible without lateral bone augmentation. For that reason, narrow diameter implants (NDI) can be an alternative to treat this kind of decreased bone width cases[1].

## INTRODUCTION

Increasing life expectancy of world population expanding every decade brings increasing health problems and additional demands to health sector. This rapidly changing information age brings also to dentistry new challenges. The acceptable treatment plans for edentulous patients of the past are in today's world becoming no more acceptable. Therefore, these new patient demands pushing dentistry and most specifically the implant dentistry to develop more acceptable solutions for this new generation patients. Since the 1980's dental implants become a very dominant field in dentistry especially as a treatment solution for the maladaptive patients. The development of implant supported or retained restorations has revolutionized the treatment possibilities of patients[2]. Increasing demands of implant related restorations are a great challenge in today's dentistry. Even there is a growing demand of implant related restorations economic limitations of elderly patients still the greatest obstacle on this field[2]. According to current literature estimated 10% of the world's population is edentate, but on the other hand only 1.7% have received implant treatment[3]. Also, decreasing the treatment time and complication possibilities of highly sophisticated augmentation procedures are another consideration for mostly aged patients who wants to undergo implant related prosthetic treatments.

While, planning the implant supported prosthetic rehabilitation of the posterior jaw many factors such as the condition of the remaining teeth on the mouth, the quality and dimensions of the residual bone, type and extent of edentulism, nature of the opposing arch, existing restorations, habit related force factors generated by patient and the maintenance of oral hygiene should be taken into consideration.

Narrow diameter implants begin to appear as a treatment alternative on surgically compromised areas in last two decades. Using of NDI's on anterior single tooth areas is widely acceptable and a well documented treatment option in implant dentistry but the use of these implants on the posterior edentulous areas is not a widely accepted treatment option.

**LITERATURE**

In current literature many longitudinal studies showed the reliability of osseointegration in the partial and complete edentulous clinical situations[4]. To create ideal biologic conditions and achieve optimal implant placement ≥1.5 mm of bone must surround the entire implant surface[4-6]. In implant dentistry, the use of regular diameter implants generally recommended to achieve better bone to implant contact which can be very critical biomechanically to load transfer from the restoration to the bone. Also regular diameter implants mechanically have better fracture resistance than the small diameter implants[7]. But most of the extracted teeth have chronic pathologic conditions including endodontic and periodontal problems, which can result in severe bone defects[8, 9]. Also natural healing after extraction can cause reduced bone volume at future implantation areas[10]. Therefore preservation of residual bone after extractions is very critical for future implantation[11]. Placing a standard diameter implant in reduced bone volume areas may increase the risk of implant complications and failures[4].

To achieve three dimensional available bone volume for future implantation areas several advanced surgical techniques such as guided bone regeneration[12], distraction osteogenesis[13] and autogenous bone grafting treatment[14] reported in the literature. These techniques have proven to be successful in different clinical scenarios. Nevertheless, these advanced augmentation procedures have also some down sides such as unpredictable complications including infection and wound exposure, prolonged healing time and additional cost[15]. Complication fear of aged patients also limit the use of this kind of procedures frequently[3]. Therefore, case selection for advanced implant and augmentation procedures is very important factor for success. To reduce the risk factor of this kind of procedures by using a narrow diameter implant can be a better option than a wider implant in some good selected cases[16].

The NDI's mostly designed for restricted interdental spaces like mandibular incisors and maxillary lateral teeth areas[17, 18]. For example, in anterior segments[19], an inter-radicular distance of less than 6 mm contraindicates the use a 3.75 mm regular diameter implant because of the possibility to damage adjacent roots and also when the bucco-lingual width of the edentulous crest is insufficient it is contraindicated to use standard diameter implants. Therefore, in these cases narrow diameter implants can be safer alternative as a treatment option[4, 5, 17, 20-22].

The definition of a narrow diameter implant is not well established in literature. There is no universally accepted classification of implant diameters. But generally, in literature implants that have diameter between ≥ 3.0 to ≤3.5 mm named as narrow diameter implants and implants that have diameter between ≥ 1.8 to ≤ 3.0mm named as "mini" implants[23, 24].

“Mini” type of implants planned to retain removable complete dentures but some case reports showed some compromised cases that were restored by 1.8 to 3.3 mm diameter implants to support fixed partial dentures[19, 25, 26]. Mini implants primarily used as a transitional implant to support temporary prosthesis during healing period of larger diameter implants. However, some clinical reports succeeded to show that the use of these type of implants alone or in combination with larger diameter implants in selected circumstances can give similar successful results[3, 27, 28]. In some cases with deficient bone volumes, the use of narrow diameter implants prevents the need for the complex bone augmentation procedures or possible orthodontic treatment needed for the future prosthesis[4].

The successful clinical performance of narrow diameter implants referred by clinical reports and long-term systematic studies in literature. Saadoun and Le Gall (1996) in their 8 years clinical study inserted 1499 Steri-Oss (Nobel Biocare) implants in 605 patients. In this study 306 small diameter implants of different lengths (8, 10, 12, 14, and 16mm) were inserted and among them 296 narrow diameter implants brought into function. These authors reported 89% success rate for these implants. Among failed implants the 8-mm implants were with the highest failure rates of 43.2%. The authors advise against the use of short small-diameter implants[4, 19, 29].

Another study presented showed the 3 year preliminary results of 370 Osteo Ti implants (Osteo Implant Corp., New Castle Pennsylvania) that had been placed in 135 patients. The small-diameter implants were manufactured from titanium alloy. No failures were reported among these small-diameter implants[4, 30].

But at the same time there are several weaknesses of NDI's that can limit their use routinely in implant dentistry. The reduced cross – section of narrow diameter implants that cause reduction of the fatigue strength specially when they are exposed to higher occlusal loads[31]. Also, the decreased ratio of the implant diameter to the occlusal surface area can induce cantilever effects on implants and this can cause unwanted overload on an implant. Small diameter implants have thin walls around abutment and screws which is the result of the reduced diameter of the implant. This can decrease fracture resistance of implant fixture and screw[16, 32].

These reduced mechanical strengths related problems can be compensated by alloying pure titanium with other materials. Vanadium and Aluminum are the most popular materials that are used as combination with Titanium to create Ti-6Al-4V alloy which is very commonly used in commercially available dental implants. However these materials have also some adverse effects that reported in literature such as V (Vanadium) and ionized Al (Aluminum) which present in Ti – 6Al- 4V alloy may release into the tissues around the implants and inhibit osteoblast differentiation and leading to the inhibition of new bone growth or even osteonecrosis[33-35]. Common Ti alloys (3+5 biphasic metal structure) do not allow for surface modifications such as SLActive which has demonstrated the faster osseointegration capacity and reduced healing times with greater bone to implant contact at earlier healing periods due to its hydrophilic properties[36, 37]. Therefore, Ti alloys that do not contain these materials may have better tissue response by avoiding these adverse effects[35]. In vitro experiments on tissue reactions to different elements have shown that Ti and Zr (zirconium) are highly biocompatible materials and have no adverse effects on the growth of osteoblasts that therefore alloying these materials can be

favorable according to biologic and biomechanical properties[38-40]. Nevertheless, in these studies authors still incorporated the Zr into Ti-Al-V alloys that potentially allows the release of Al and V ions into the tissues[40].

The TiZr base alloys have been referred to be favorable materials for use in medical field[40]. Better biocompatibility, improved wear resistance, increased elongation and fatigue strength compared with conventional commercially available pure titanium and similar modulus of elasticity to bone of these alloys have been shown[35, 41, 42]. These materials also can be sandblasted and acid etched like titanium implants[42]. The Roxolid® implant (Institut Straumann AG, Basel, Switzerland), TiZr alloy, made of 83–87% Ti and 13–17% Zr was recently introduced for the fabrication of implants with narrow diameter[43]. Titanium – zirconium alloy allows SLActive modification that has better mechanical strength and improved biocompatibility than existing Ti alloys. Also enhanced osseointegration capabilities proved by human and animal studies [35, 44, 45]. Nevertheless, the long-term clinical results of short TiZr implants is still unknown. While studies search for survival of narrow diameter and short implants (≤ 13 mm) compared to longer ones (> 13 mm) also remained unexplored [42].

In areas where mesio-distal space is too wide**,** especially on anterior regions, placement of narrow diameter implants may lead unacceptable esthetic results due to poor emergence profile[46] or black triangles created around final restorations. Also, on posterior region when replacing molar tooth, it is impossible to provide optimal root form support especially when there is insufficient bucco-lingual width, with one cylindrical implant. These situations also may cause unwanted food impaction and related excessive plaque accumulation around implants [16].

Esposito et al. showed the biologic relevance of appropriate distance between implant and natural tooth and stated that a minimum of 1.5 mm of space is required between a tooth and an adjacent implant surface[47, 48]. Elian et al. demonstrated that 3 mm of available bone is needed between two adjacent implants for success[49]. In general treatment inclination, use of one implant per root has been recommended as the appropriate treatment plan for implant mandibular molar replacement[50]. However, the osseous quantitative requirements limit the use of conventional standard size implants (3.75 mm) in many clinical situations. In these kind of clinical cases alternatives like small diameter implants can be taken into consideration. Small diameter implants also allow for successful placement with adequate osseous support[47]. Saadoun et al. showed a minimum interdental space of 12.5 to 14 mm is necessary to successfully place and restore two 3.25-mm-diameter implants for a missing molar [51]. Nevertheless, the study of Balshi et al. indicated that two standard-diameter implants (3.75 mm) can successfully be placed in sites with as little as 10 mm of interproximal space and they pointed that the more important measurement is at the level of the crestal bone, where two implants were placed in as little as 12.0 mm of interdental space[46].

Treatment of a missing molar tooth by two implants can allow for enhanced prognosis by increasing implant bone surface area by splinting[47]. Splinting two implants on a molar area can help to preserve and maintain crestal bone. It also provides better support to final implant supported restorations against bucco-lingual and mesio-distal bending. Also, by decreasing the rotating forces around implant axis, the use of two splinted implants can reduce loosening of implant components. Two implants also eliminate the inherent mesio-distal cantilever and reduce the potential for overload and the complications that related like abutment screw loosening or abutment

fracture. In comparative study Balshi[50] was shown that molar restorations supported by two implants exhibit fewer complications than those supported by one implant [46, 50]. In addition, splinting two small diameter implants reduces the size of the gingival embrasures often present when a single implant replaces a mandibular first molar. This problem may become a patient's chief complaint after final restoration placement[47].

Even there are some mechanical disadvantages of small diameters implants; there may be some physiological advantages too. Small diameter implants have fewer amounts of linear or circumferential percutaneous exposure and bone displacement which may expose less implant-gingival attachment to bacterial attack. During implant site preparation, the 4mm diameter implant has four times the osseous displacement as compared with the 2 mm diameter implant. Less osseous displacement may be a physiologic advantage for the very small diameter implant in that there may be more of an available osseous blood supply for the implant supporting bone or fewer barriers to the blood supply. Larger barrier to blood supply or angiogenesis may contribute to the classic "resorption to the first thread" in the larger implant. This phenomenon does not seem to be prevalent with the small diameter implants[27].

The use of wider diameter implants on the edentulous posterior jaw segments is a common treatment strategy because majority of reports suggests that load bearing capacity of wider diameter implants is important especially where the occlusal load is higher. However, in some cases, posterior segments after extraction may not allow the placement of standard or wide diameter implants and sophisticated reconstruction procedures are not always acceptable by the patients because of their higher cost and their higher morbidity. In recent years several reports

referred the use of narrow diameter implant on anterior zone as well as posterior edentulous or complete edentulous cases[4, 19, 21, 28, 52]. The cyclic loading that is produced by human occlusion during jaw functions may induce metal fatigue in small diameter implants[27], screw loosening[53] fracture of posteriorly placed narrow diameter implants[52]. The occlusal forces on the posterior parts of the jaw can exceed 1000N/cm of force, but at these areas direction of forces are mostly in the axial direction and the off-axial vector of forces are less[27]. The forces in the anterior jaws can be about one third of the posterior forces, 50 to 200N which are delivered not axially but off axially which is more vulnerable direction for the implant[27]. Although there are some known biomechanical disadvantages for NDI's recent data regarding to posterior NDI's demonstrating almost the same success rate to standard diameter implants [1, 54-56].

Jung et al. in their systemic review showed, for single implant supported crown restorations cumulative 5-year technical complications rate that reached 8.8%[57]. Among these complications abutment and screw loosening, loss of retention (fracture of the luting cement) and fracture of the veneering material were the most common technical complications. The cumulative 5 year standard implant fracture rate was 0.18%[43, 57] . Nevertheless, the fracture of the narrow diameter implants was rarely observed in clinical studies. According to different studies reducing the diameter of the implants was shown to increase the risk of fatigue fractures due to lower mechanical durability which may occur after long period of function [5]. Long term studies reported the fracture rates of NDI's range from 0.67 % to 0.26% [5, 19, 22]. However another 5 years follow up study on NDI's which were splinted with each other or with regular sized implants showed no signs of fractures[5]. Therefore, use of small diameter or standard diameter implants by multiples to support fixed restorations on posterior

regions of the jaws exhibit fewer complications like excessive loading and implant/abutment fracture than those supported by one implant[27, 50, 58]. On this purpose very small diameter implants can be used in conjunction with standard diameter (3.75-4.1 mm) implants to support a fixed prosthesis where there is an area of thin bone next to or near an area that will accept a standard diameter implant[27].

According to Polizzi et al. [21] and Vigolo et al. [52] survival of NDI's on mandible was shown higher than maxilla. The greater bone density of the mandible referred as a reason of this better survival rates. But on the other hand, Arisan et al. [59] showed no significant differences between jaws on survival rates of these implants. Most of the studies reviewed in literature placed NDI's both posterior maxilla and mandible with average success rate of NDI's were 98%. From this result, NDI's probably can be used successfully in both jaws and in sites where there is a low quality of bone, if patient selection done carefully and correct procedures implemented during implantation [28].

| Author (Year) | Lost implant length (mm) | Failure type | Survival rate (%) | Success rate (%) |
|---|---|---|---|---|
| Akca et al. (2013) [42] | - | - | 100% | 100% |
| Altinci et al. (2016) [60] | - | - | 100% | 100% |
| Anitua et al. (2015)[58] | 10mm (1) | Lack of osseointegration(1) | | 97,30% |
| | | Prosthesis fracture | | |
| | | Poor esthetic outcome | | |
| Chiapasco et al.(2012)[61] | - | - | 100% | 100% |
| Comfort et | No Info. | Lack of | | 96% |

| | | | | |
|---|---|---|---|---|
| al.(2005)[62] | | osseointegration(1) | | |
| Degidi et al. (2009)[63] | - | - | 100% | 100% |
| Degidi et al. (2008)[64] | 13(1) (Max) | Lack of osseointegration(3) | 99,37% | 99,40% |
| | 15(1) (Max) | | | |
| | 18(1))(Max) | | | |
| El-Sheikh et al. (2014)[18] | - | Prosthesis decementation(1) | 100% | 100% |
| Flanagan et al. (2008)[27] | - | - | 100% | 100% |
| Flanagan et al. (2015)[65] | No Info. | Lack of osseointegration (3) | 92% | 92% |
| | | Prosthesis decementation (4) | | |
| | | Implant fracture (1) | | |
| Lambert et al.(2015)[66] | No Info. | Infectious problems (2) (Max) | 94,70% | 94,70% |
| Saad et al. (2016)[1] | 0 | - | 100% | 100% |
| Maló et al. (2011)[67] | 10(4) | Lack of osseointegration(12) | | 95,10% |
| | 11.5(2) | | | |
| | 13(1) | | | |
| | 15(5) | | | |
| Mangano et al. (2013)[68] | - | - | 100% | 94,60% |
| Mazor et al. (2012)[69] | - | - | 100% | 100% |
| Romeo et al. (2006)[19] | 10(1) | Infectious problems(1) | 98,10% | 96,90% |
| Tolentino et al. (2014)[70] | No Info. | No Info. | 95,20% | 95,20% |

Immediate loading means placing the final or provisional prosthetic restoration immediately or within 48 hours after the surgical procedure. It is referred to appropriately as immediate loading when the prosthetic restoration is in occlusal contact; otherwise, it is known as immediate restoration without loading (IRWL - immediate loading without loading)[28, 71-73]. According to Degidi et al. [74] immediate restoration of NDI's seems to be a safe and predictable procedure, but still in their study slightly more bone resorption found compared to delayed loaded NDI's.

Malo et al.[67], Misch et al. [75, 76] showed no influence between one-stage technique, two-stage technique either immediate or delayed function surgical technique to the outcome of survival rate for NDI's.

Arisan et al.[59] found MBL, BI and PI were lower in one-stage (piece) implants compared with two-stage (piece) implants although their results were not statistically significant. Hence the survival probability value of one-stage implants was higher than two-stage implants but the difference was statistically insignificant. Keller et al.[77] showed better peri-implant microflora conditions due to the lack of micro-gap and in one-stage implants with transmucosal extension. The one-piece implant design with transmucosal extension could be beneficial in patients experiencing difficulty with plaque removal because of carrying the critical abutment–prosthesis margin connection to the soft tissue level, which is in the bone level in two-stage implants[59]. King et al.[78] have shown that the level of any micro-gap in the surrounding alveolar bone determines an increase or a decrease of bone loss. The reason for this reaction may be related to the presence of microbial colonization at the level of the interface. Also, the peri-implant mucosa is allowed to heal longer in one-stage implants and is not subject

to further disruption during the restoration phase, as in two-stage implants[59].

## CONCLUSION

In current literature showed similar success and survival rates for NDI's. Therefore, in well selected cases NDI's may offer alternative treatment option for edentulous posterior implant supported rehabilitations[61]. Still, use of single un-splinted narrow diameter implants on posterior zone has to be considered with caution, because of the biomechanical properties of these implants. It is recommended to use this type of treatment option in cases with tooth-protected areas or at the limited occlusal loads because of opposite dentition. This kind of treatment option can be considered as a low-cost solution and efficient enough, which reduces the surgical risk of complex surgical modalities to achieve wider ridge volumes to place standard diameter implants. Long-term follow-up clinical data are needed to confirm the clinical performance of these implants.

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