

Narrow-diameter implant in prosthodontics treatment

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ABSTRACT

Insufficient bone volume and narrow mesiodistal space often compromise Standard Diameter Implant (SDI) treatment planning. In order to achieve successful results, these compromises may incorporate prior treatment such as *guided bone regeneration* (GBR), block bone grafting, or distraction osteogenesis that requires extra time and cost and could result in unpredictable complications. A *narrow diameter implant* (NDI) is smaller than a standard diameter implant with a diameter less than 3.5 mm. This scoping review was performed to assess the use of NDI in prosthodontic care. It is concluded that NDI reasonably resembles SDI clinical success rate in terms of periodontal health, marginal bone remodeling, restoration, and patient satisfaction. The NDI offers similar survival rate to SDI, with promising long-term esthetic outcomes and can be used as the primary treatment alternative in restoring single tooth or splinted crowns in the anterior and posterior region, especially with narrow mesiodistal space.

Keywords: narrow diameter implant, small diameter, implant, treatment

INTRODUCTION

Missing teeth is a very common occurrence in dentistry. Nowadays patients' expectations are already shifted and see tooth loss as a very negative effect that can affect their daily life.¹ Patient consciously seeks treatment when experiencing tooth loss in the anterior region because it's affected their aesthetics, but when it happens in the posterior region, the patient tends to delay the treatment however patient should be educated more about the need for tooth replacement.² Clinically, the missing tooth that is not replaced can lead to extrusion of the antagonist teeth which will interfere with occlusion and complicate further rehabilitation. The tilting of the adjacent teeth is also one of the consequences of not replacing missing teeth and can increase periodontal abnormalities and caries development.³ Thus, rehabilitation treatment for missing teeth should be able to restore masticatory function, speech, comfort, and aesthetics.²⁻⁴ Several treatment options to replace lost teeth include removable dentures, fixed dentures, and also implant-supported dentures.²

Modern dentistry has developed towards restoring the patient's teeth to their original condition in contour, function, comfort, esthetics, speech, and restoring to a healthy condition by removing disease from the tooth or replacing it with a prosthesis. The trend of using implant-supported dentures compared to conventional removable dentures is also increasing in various countries such as South Korea, countries in Europe, and America. Therefore, implants in the field of dentistry continue to be developed with research, diagnostic tools, treatment plans, designs, cutting-edge materials, placement techniques, and predictions of success in various clinical situations.⁴

Implant restorations are reported to have had a high success rate, both in partial and total tooth loss.⁵ By 2020, 90% of prosthodontists were routinely working on implant-supported restorations for both fixed and removable restorations. Implants are chosen by prosthodontists because they have several advantages over fixed or removable dentures, including maintaining bone, increasing occlusion stability and increasing chewing power, improving phonetics and restoring oral function, reducing the size of the denture (does not require a palatal base and does not require additional retention of the buccal and labial flange), improves the stability and retention of removable dentures, and can support both fixed and removable restorations, resulting in a more permanent denture. Although it is widely known, the development of implant restoration is still going to grow.⁴ The requirements for implant placement require adequate bone volume and adequate mesiodistal edentulous space so that the implant can be placed properly. If there is a lack of bone volume, it can require a guided bone regeneration.⁵

Implants are well known for their qualified nature to be the most ideal treatment of choice for missing tooth cases. Some of the implant properties are designed to optimize implant placement, can produce primary stability, and must be able to distribute stress on the bone, and the structure on the implant surface must be able to provide cell adhesion and differentiation during the bone remodeling process.⁴ For implants with a standard diameter or called *standard-diameter implant* (SDI) the average implant width is 3.75-4.1 mm and the required installation distance between implants or with neighboring teeth is 1.5-2 mm so that a total distance is

required more than 6-6.5 mm in order to obtain a good implant placement result.^{5,6} However, in some clinical cases, many cases of the missing tooth were found which conditions already impossible to install SDI due to thin buccal lingual bone conditions or short mesiodistal edentulous distances. Although in bone conditions that do not meet the standard of implant placement, horizontal bone augmentation can be done such as bone splitting, block bone grafting, and distraction osteogenesis, these techniques have procedures that are too complicated, prolonged treatment time, are quite expensive, and unpredictable complications that cannot be avoided.⁷

A treatment plan with NDI can be an alternative treatment in cases with inadequate bone volume both in the buccolingual and mesial-distal directions.⁵ The term *narrow-diameter implant* or commonly called NDI has different size classifications in the existing literature, but in general the implant diameter is said to be less than 3.5 mm.⁸ NDI began to be known in 1995, with the development of existing technology the use of NDI is increasingly popular.⁹ However, the use of NDI does not have the same indication as SDI. Therefore, NDI has a specific indication in the form of limited mesiodistal space, for restoring mandibular incisors and maxillary lateral incisors.¹⁰ There is still debate over the use of NDI, especially in the use of the posterior region and as a single or splinted crown.^{7,10} NDI is expected to be applied more widely in prosthodontic treatment for elderly patients, and patients with inadequate soft and hard tissue support, so that can shorten the treatment sequence also costs incurred by patients.^{6,7,10,11}

This scoping review assesses the uses of NDI in prosthodontic care. In addition, to see how the considerations, indications, and evaluation of the NDI placement supported various types of fixed denture restorations both for the anterior and posterior regions. Therefore, it is hoped that this scoping review can improve the understanding of dentists and as a basis for scientific evidence on the use of NDI in prosthodontics treatment.

METHOD

The writing was made as a scoping review based on the definition presented by Arksey & O'Mailey. The objective of this scoping review is to summarize and present the result of research that has been conducted about one part of certain topics or field science. The making of this scoping review was arranged in several stages, determining the question study, determining the type of relevant

research, conducting a selection study, collecting data on a chart, and composing.¹²

The research question used in composing this scoping review is *what prosthodontics treatment can be done with a NDI?*. The defined population is subject with tooth loss and treated with NDI.

Search literature was carried out with an electronic search using PubMed, EBSCO, and Scopus. The search strategy uses these specialised terms: *((small-diameter) OR (narrow)) AND (implant) AND (restorations)*. The search of the literature has been given several limitations published in 2017-2021, clinical studies in humans, also published in English. Inclusions and exclusions criteria used for selecting literature have been obtained and can be seen in table 1.

Independently screened all the titles and abstract that has been found and excluded studies for their irrelevance to the review based on the inclusion and exclusion criteria. Several literatures were eliminated due to the unavailability of full text and duplicated from the three search engines. Results of the collected information will be displayed in a table with relevant information such as the author's name, year published, objective, method, and conclusion.

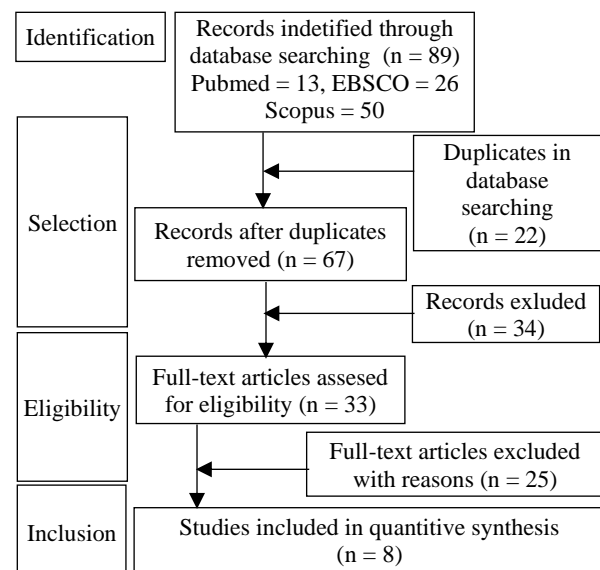


Figure 1 PRISMA Flow diagram for the scoping review process

Review of literature

The electronic search using keywords on PubMed, EBSCO, and Scopus identified 89 articles. 22 articles are excluded because of duplication from the three search engines. Several articles were excluded due to irrelevance to the review based on inclusion and exclusion criteria. A full-text search of the entire remaining findings was conducted and read thoroughly. The remaining li-

Scoping review

Table 1 Inclusion and exclusion criteria

Criteria	Inclusion	Exclusion
Period	Published January 2017 – December 2021	Published before January 2017
Language	English	Non-english
Subject	Patients	Non-patients
Concept	Clinical evaluation and definitive restoration using NDI	Using non-NDI
Context	Reporting patient's clinical evaluation.	Not discuss the patient clinical evaluation.
Design	Randomized Clinical Trial, Retrospective Study, Prospective Study, Observational Study	Case report, Consensus Report

Table 2 Basic characteristics, objectives, methods, and conclusion included in the scoping review

No	Author (Year)	Objective	Method	Conclusion
1	Francesco Pieri, et al.(2017) ¹⁰	The aim of this study is to compare 5 years outcome of NDI to SDI in supporting fixed partial denture in the posterior region (Prospective)	Evaluation on 107 patients after 5 years: 1. Prosthesis Failure 2. Implant Failure 3. Evaluation and biological complications 4. Major and Minor Prosthetics Complications	5 years evaluation study indicate that the survival rate of NDI was comparable to SDI in supporting Fixed Partial Denture in the posterior region, but the prosthetic complications in NDI were significantly higher than the SDI.
2	Stuart J. Froum, et al. (2017) ⁵	Evaluation of peri-implant bone remodeling, healing of the soft tissue, aesthetic, also patient satisfaction on NDI loading (1.8mm – 2.4 mm) in the incisivus region. (Retrospective)	Evaluation on 19 implants in 14 patients after 3 – 14 years post-loading: 1. <i>Bone Remodelling</i> 2. Bone Loss 3. Marginal recession 4. Bleeding on Probing 5. <i>Papila Index Score</i> (PIS) 6. Patient Satisfaction	<ul style="list-style-type: none"> • No implant failure or prosthetic complications indicating a 100% survival rate and 84,2% success rate. • All patients reported being satisfied with the result. • Respectively there are 1,99mm and 1,84mm in mesial and distal bone remodeling. • There is bone loss on average of 0.14mm and 0.17mm on the mesial and distal bone sides.
3	André Nilsson, et al. (2021) ¹³	Restoration evaluation on the <i>single-tooth implant with one-piece yttria-stabilized zirconia abutment</i> in narrow (3,3 mm) and regular diameter implant controlled after 6 after loading in the anterior region. (Prospective)	Periodontal evaluation on 48 implants in 53 patients after 6 years of loading 1. <i>Bleeding on Probing</i> (BOP) and plaque index on the mesial and distal implant and adjacent tooth. 2. Evaluation of <i>Marginal bone loss</i> (MBL) in 3-phase: - Baseline (prosthetic loading) - First control (about 20 months) - Final registration (about 54 months) 3. Questionnaire function evaluation and aesthetic while final registration using Visual Analog Scale.	<ul style="list-style-type: none"> • There is no failure on the implant that concluded a 100% survival rate. • 3 changed restorations for another reason than failure. • 5 fracture of <i>internal one-piece zirconia abutment in 3.3mm NDI</i> • The majority of patients are very satisfied with the aesthetic and function of the implant restorations.

4	Pablo Galindo-Moreno, et al. (2017) ¹⁴	To investigate the distance between NDI and adjacent teeth influence the marginal bone level up to 3 years of placement. (Prospective)	<p>Evaluation on 3 years from 83 implants in 59 patients.</p> <ol style="list-style-type: none"> 1. Marginal bone analysis based on radiograph on examinations in first examinations, implant placement, restoration delivery, 6 months, 12 months, 36 months output. 2. Distance between adjacent tooth and implant at the time of implant placement <ul style="list-style-type: none"> - Narrow: 3,2 – 5,54 mm - Regular: 5,55 – 7,14 mm - Wide: 7,15 – 10 mm 	<ul style="list-style-type: none"> • The current study confirms that there is no influence of distance between the implant and adjacent tooth in NDI. • But this study found less MBL occurred in narrower distance to adjacent tooth. • In this study, MBL changes in adjacent teeth were not significant.
5	Jun-Yu Shi, et al. (2018) ⁷	Evaluation of the long-term survival, complications, peri-implant conditions, MBL, and patient satisfaction of FPD supported NDI in the posterior region (Retrospective)	<p>Evaluation on 98 implants in 67 patients, 8 years follow up</p> <ol style="list-style-type: none"> 1. Long-term survival rate calculated with Kaplan-Meier Survival Plots. 2. Peri-implant condition while 8 years follow up 3. Evaluation of MBL between baseline and follow-up in mesial and distal restorations. 4. Complications rate per implant per patient. Questionnaire function evaluation and aesthetic while final registration using Visual Analog Scale. 	<ul style="list-style-type: none"> • NDI could be a predictable treatment alternative for the long term. • This study showed high survival rates, high patient satisfaction, acceptable complication rates, and also marginal bone loss could be achieved.
6	Saba Sameeh Ghazal, et al. (2019) ¹⁵	NDI (3.3mm) Ti-Zr alloy implants with a chemically modified hydrophilic surface are not inferior in regard to crestal bone level compared to SDI (4.1mm) implants with the same material in a single crown on the anterior or posterior region. (RCT)	<p>Periodontal evaluations on 47 patients in 1-year follow-up.</p> <ol style="list-style-type: none"> 1. Crestal bone level change in ND and SDI while implant placement and implant loading (IP dan IL) 2. Success rate, survival rate, gingival recession, and patient satisfaction. 	<ul style="list-style-type: none"> • There is no significant difference found in both periodontal evaluations indicating that NDI TI-ZR with a chemically modified hydrophilic surface is not comparable to SDI and can be used as an alternative treatment plan.
7	Peron Christian, et al. (2020) ⁶	Evaluate within clinical and radiographic parameters, implant survival and success rate of single, narrow, immediately loaded implant (3.1 mm) placed in fresh extraction socket or healed socket in the anterior region (Prospective)	<p>Evaluation after 2 years in 16 patients:</p> <ol style="list-style-type: none"> 1. Implant success and survival rates. 2. Average MBL of healed and fresh socket. 3. Average Pink Esthetic Score (PES) within 1 year and 2 years follow-up. 4. The probing average on 2 years follow-up. 	<ul style="list-style-type: none"> • NDI can be used with a provisional restoration as a minimally invasive treatment in healed sites with thin bone crest and for the presence of reduced interdental spaces. • Soft and hard tissue stability was achieved in a fresh extraction socket with immediate provisional restorations.
8	Bielemann AM, et.al. (2018) ¹¹	Compared the peri-implant health, implant stability, and concentrations of pro and anti-inflammatory cytokines in the peri-implant crevicular fluid (PICF) in mandibular edentulous patients under conventional loading (CL) and immediate loading (IL) in using NDI as a retainer of mandibular overdentures. (RCT)	<p>Clinical evaluation on weeks 1, 2, 4, 8, and 12 months in 20 patients after surgery::</p> <ol style="list-style-type: none"> 1. Peri-implant condition 2. <i>Implant Stability Quotient</i> (ISQ) 3. Marker Inflammatory <i>Peri-implant Crevicular Fluid</i> 	<ul style="list-style-type: none"> • Probing depth was better in the IL group, but there is no significant result for others. • Implant stability and marker inflammatory are more stabilized in the CL group.

terature was studied thoroughly with the full-text version and it was obtained 8 articles. The flow of literature search used in this scoping review can be seen in Fig. 1, while the results of the literature used in this scoping review can be seen in table 1.

RESULTS

The electronic search in the database Pubmed, Ebsco, and Scopus provided a total of 89 titles that were considered potentially relevant. There are 8 full-text that include in this study, such as four prospective, two retrospective, and two RCT. Participants that were included in the studies were 16-107 participants. The time of the study also varied 1-14 years. All the studies included partial edentulous either in the anterior or posterior region. Aspects that were used in the studies are the survival rate and success rate, periodontal aspect, also VAS questionnaire, and patient satisfaction.

DISCUSSION

First introduced by Brandemark, implant has been used for a long time, along with the development of the implant technology the uses of implant has widely indications. Nowadays, NDI are available in almost all implant brands and designed significantly for mesiodistal space less than 6 mm or space between the implant and the adjacent tooth or buccal lingual bone height is 2 mm.^{5,6,9} Narrow interdental space, usually in the incisor and premolar regions, is one of the main indications for NDI, but after shorts and long studies, it has been indicated for the other region also type of work.

Prosthodontic treatment is the final stage of dental treatment which include rehabilitation after all the pathological conditions are met. In SDI many pathological conditions are resulting in bone loss that needs to have another set of surgeries for the pre-prosthodontics treatment, but with a NDI, some surgeries can be avoided. The NDI would be beneficial to decrease the rate of bone augmentation for implant insertion, this can help elderly patients or patients with a medical risk factor to have reduced surgical invasiveness for implant placement. Also, there are concerns and restrictions against time-consuming treatments associated with complications and pain. For patients with systemic conditions or elderly patients, NDI can be one of the main alternatives if patients need an implant but without any pre-surgery, because NDI needs less space and bone volume so can be placed directly and resulting in shorter treatment time and reducing the risk of complications.^{6,9,15}

As one of the alternative treatment plans, NDI

certainly has advantages and disadvantages such as reported in in-vitro studies and finite-element analysis that overloading of NDI may result in peri-implant crestal bone resorption which will compromise the longevity and success of the treatment.¹⁰ Bone thickness around the abutment or implant screw also increases the risk of fracture both for the implant fixture or screw.⁷ However, in a retrospective study of NDI placement for splinted FPD in the posterior region, the success rate and marginal bone loss were comparable with SDI.¹⁰ A 10 years retrospective study also indicated that single and splinted FPD both in the anterior and posterior region showed a reasonable success rate also a high patient satisfaction rate. This is due to the improvement in the material of implant fixture with Ti-Al-V alloy material used to manufacture NDI to increase fatigue resistance and biocompatibility.⁹ Moreover, further research is needed to evaluate and predictable outcome of treatment using NDI in the molar region.⁷

This scoping review assesses the uses of NDI in prosthodontic care. Our scoping review identified consideration, indication, restoration, and evaluation of NDI. From the eight literatures that match the inclusion criteria, there are differences in study design, implant diameter size, restorative materials, and evaluation methods so there are possibilities that can lead to limited information and inconsistencies in the summary.

Judging from the research design in the seven selected literatures, there are four prospective studies^{6,10,13,14}, two retrospective studies^{5,7}, and two RCT studies^{11,15}. Based on the size of the implant diameter used, there is literature that uses implants size 1.8-2.2 mm⁵, 2.9 mm^{11,15}, 3 mm^{8,12}, 3.1 mm⁶, dan 3.3 mm^{7,13,15}. For restorative materials, some literatures do not specifically mention the restorative materials⁵, there is literature using PFM^{7,14,15}, lithium disilicate^{6,13}, and there is literature that includes both materials.¹⁰ In these eight literatures, some researchers evaluate only based on objective^{6,10,11,14,15} also objective and subjective^{5,7,13} from patients.

In a study conducted by Galindo et al on the implant placement of 83 NDI in 59 patients and evaluation every six months to 36 months in the maxillary and mandibular incisor regions, a 100% success rate was obtained with an average marginal bone loss of 0.0-0.50 mm in 36 months follow-up both in the anterior and posterior region. Distance from implant to adjacent tooth was counted narrow, regular, or wide but marginal bone loss was found to be less in the narrow distance. These re-

sults are in line with the study conducted by Peron and Romanos in 16 patients with 16 NDI in the anterior region with a follow-up period of two years for both newly formed and healed sockets having a 100% success rate.¹⁴



Figure 2 (a) Clinical features of the mandibular anterior region before and after NDI placement with restoration follow-up for 6 years, (b) radiographic periapical before implant placement, immediate implant placement, and 6 years follow-up after restoration.⁵



Figure 3 (a) Clinical features of the posterior region before, during, and after insertion of the NDI with restoration follow-up after 2 years, (b) radiographs periapical before implant placement, during implant placement, and 2-year follow-up after restoration.⁶

Evaluation of the patient satisfaction obtained by Stuart et al, Nilsson et al, and Shi et al showed that most patients were satisfied with both the aesthetic and functional results resulting from the installation of NDI.^{5,7,13} Study conducted by Stuart, et al of 14 patients reported bone remodeling with an average of 1.9 mm and 1.84 mm in the mesial and distal parts of the implant, and only 5 implants experienced bone loss but only 0.14 mm in the mesial and 0.17 mm distal to the follow-up period of 3-14 years.⁵

Nilsson, et al also reported that 14 patients with 16 NDI had a 100% success rate despite 5 fractured restorations with one-piece zirconia abutments. Based on a study conducted by Shi, et al with a follow-up period of 8 years in 67 patients with 98 NDI it was found that both single and splinted restorations in the posterior region had a success

rate of 96.9% at implant level and 97% at patient level. The mean MBL obtained was 1.19 mm at the implant level and 1.15 mm at the patient level, and only 8.5% of implants and 9.2% of patients had peri-implantitis; 89.2% of patients were satisfied with the aesthetics produced, this was in line with 84.6% of patients satisfied with the function obtained.¹³

In the study of the use of NDI in the restoration of the posterior region reported by Shi et al, also a similar study was carried out by Pieri et al reported 113 NDI in 49 patients compared to 126 SDI in 58 patients, there were 12 cases of prosthesis complications but only 2 cases of prosthesis complications in SDI. However, this is inversely proportional to marginal bone loss in NDI patients, only 36.7% experienced a bone loss of more than 1 mm, and 8.2% experienced more than 2 mm, this was quite far adrift in the SDI group who experienced more than 1 mm bone loss (43.1%) and losses above 2 mm (13.7%). Implant success rates at the 5-year follow-up period for the NDI were 99.1% and SDI 96.8%.¹⁰

In a study using titanium-zirconium alloy implant material by Ghazal, et al, similar results were also found. At one year follow-up, the success rate was 100%, crestal bone loss was only 0.27-0.34 mm and this figure was lower than the use of SDI with the same implant material, as well as in gingival recession and also satisfaction levels of patients did not differ significantly between SDI and NDI.¹⁵

ARCT conducted by Bielemann et al on 20 patients with edentulous mandibular. It was reported that 2 NDIs were installed in the anterior mandibular region as retention of the mandibular overdenture, 10 patients were carried out with the conventional loading protocol, namely MO installation 12 weeks after implant placement, and 10 patients underwent immediate loading with MO installation directly after implant placement. Obtained on the *immediate loading protocol* (IML) probing depth results are better than the *conventional loading* (CL). However, in the CL group, the implant stability was better and the number of inflammatory markers was lower. The other periodontal parameters were not statistically significant. In clinical results, both CL and IML showed good osseointegration in the use of NDI as a retainer for *mandibular overdenture*.¹¹

In line with the scoping review question and objectives, there were limitations to the search to studies NDI in prosthodontics treatment. Most of the literature had a follow-up of less than 5 years, even for the mandibular overdenture supported by NDI, the follow-up was conducted only after 1 year. Further studies with longer follow-ups are needed to

determine the long-term result of NDI as a prosthodontics treatment.

The other limitation is the lack of reports on using NDI as the supported FPD in the posterior region both in single and splinted crowns especially in the molars region. In a study conducted by Shi, et al even though there was the use of NDI in the molar region but the population was still less than in the premolar region. So that more research is needed to use NDI as an alternative option for supported single or splinted FPD in the molar region. For the last addition, the diameter of the NDI used in the scoping review is all in different sizes, so it is necessary to conduct further research on the use of the right diameter for each treatment plan.

In conclusion, our scoping review identified that a NDI has a reasonable clinical success rate in terms of periodontal health, marginal bone remodeling, restoration, and patient satisfaction, also it resembles a Standard-diameter implant's success rate in follow up 1-14 years. The NDI can be the main choice in supporting single FPD both in the anterior and posterior region with short mesial and distal distance because the distance between the implant and the adjacent tooth did not affect the marginal bone level resorption both in the implant or the adjacent tooth, and also NDI has the potential to be used as a retainer in mandibular overdenture both in the conventional loading and immediate loading.

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