Clinical Application of Narrow Brånemark System Implants for Single-Tooth Restorations

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Replacing small, single incisors with implants can be esthetically challenging and difficult because of the limited amount of bone. In this investigation, 3.0-mm-diameter implants were used to support 30 single maxillary and mandibular incisors in 21 patients. The implants have been in function for 3 to 7 years, and 29 are still stable. Only 2 complications in the mandibular incisor region have occurred; 1 implant fractured (after 5 years of function) and 1 prosthesis was replaced. The overall success rate is 96.7%. The favorable results and esthetic appearance achieved suggest that replacing small incisors where light occlusal forces are present with narrower implants is a feasible treatment option.
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Initially, Brånemark System (Nobel Biocare AB, Göteborg, Sweden) implants were used to treat completely edentulous patients.[1–6] Later, they were used to treat partially edentulous patients with several missing teeth[7–12] and provide single-tooth restoration support.[13–17] However, for single-tooth restorations, it was difficult to find a good solution when space was limited; this situation was especially common when mandibular incisors and maxillary lateral incisors need to be replaced. These situations were also particularly challenging since, from an esthetic point of view, a thinner emergence profile was needed.

Bone quantity often determines whether or not an implant of standard width can be placed. For patients with congenital aplasia or considerable bone destruction resulting from periodontal disease or trauma, it may be necessary to use a narrower implant. When the buccolingual dimension is reduced and the amount of available bone is less than 4 mm wide, the placement of an implant of standard width often leads to exposure of the implant threads. Using bone chips or a membrane technique[18–23] can usually solve this problem. However, when the mesiodistal space in a natural dentition is reduced, a standard-width implant is impossible to use. In these instances it would be desirable to use an implant that has a smaller diameter.

The aim of the present study was to determine the predictability of using implants with a smaller diameter (3.0 mm) for single-tooth restorations in situations when the mesiodistal dimension caused an unfavorable condition. The study had a retrospective as well as a prospective follow-up component and included the following phases: *(1)* patient selection; *(2)* surgical and prosthetic phases according to the Brånemark technique protocol, after placing the final restoration; and *(3)* annual clinical follow-up visits.

Materials and Methods

Patient Selection. Only patients that needed replacement of a single incisor, with a reduced mesiodistal space that had to be at least 5 mm wide, were included in the study. Another clinical factor that influenced patient selection was bone quantity; ie, the bone had to have sufficient vertical dimension.

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The exclusion criteria were adverse anatomic and functional situations, such as considerable vertical tooth overlap, bruxism, or lack of space. Any history of periodontitis as the main reason for tooth loss was not considered to be an exclusion criterion, if the patient maintained good oral hygiene.[24–27]

Between 1990 and 1994, 21 patients (13 females and 8 males) with a mean age of 30 (range 13 to 58) were consecutively included in the study (Table 1). A total of 30 single-tooth restorations using 3.0-mm-diameter implants were fabricated for these patients. The reasons for tooth loss were aplasia, trauma, or periodontal disease.

Nineteen cases of congenital aplasia (63%), all maxillary lateral incisors, were included in the study. A constant finding in these patients was a thin buccolingual ridge that normally would have required a more lingual implant placement. However, making such a compromise in implant placement could have jeopardized the esthetic results. Therefore, implant placement was usually performed so that a better esthetic result could be achieved (Figs 1a to 1c), even if the more ideal position caused some residual defects, such as buccal fenestrations or dehiscences. As reported elsewhere, these defects do not seem to affect the clini-

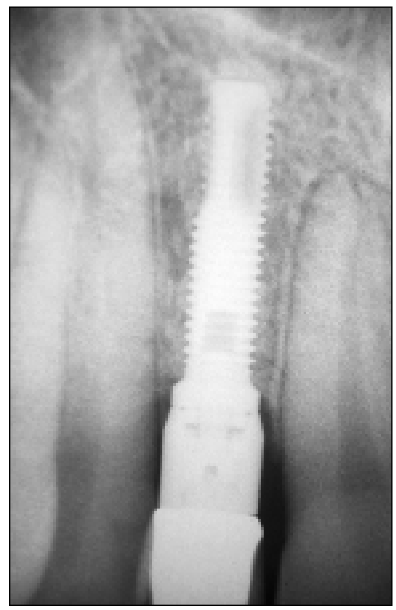

Fig 1a *(Left)* Congenital aplasia in maxilla. Preoperative radiograph showing limited available space for implant replacement of a lateral incisor in the maxilla in a young male patient.

Fig 1b *(Right)* Radiograph of the final restoration in the same patient, showing very limited marginal bone loss and a stable implant, which was a typical scenario in the majority of the cases in this study. Sometimes, during cementation, the crown does not seat perfectly on the abutment, as can be seen here in the slight misfit between the abutment and the gold cylinder.

Table 1 Distribution of Patients According to Sex and Age

Age group (y)	Males	Females	Total
≤ 20	5	4	9
21 to 30	0	3	3
31 to 40	1	3	4
41 to 50	0	3	3
51 to 60	2	0	2
Total	8	13	21

Fig 1c Clinical view of the same patient's final restoration. The ceramic crown has been stable for 6 years, and the tissue response seems to be optimal.

Table 2 Distribution of Placed Implants According to Position and Size

	Maxilla		Mandible		
Implant size	Lateral incisor	Central incisor	Lateral incisor	Central incisor	Total
3 × 10 mm	0	0	0	3	3
3 × 13 mm	14	0	0	4	18
3 × 15 mm	6	0	1	2	9
Total	20	0	1	9	30

cal stability of implants.[28] In one patient with maxillary permanent lateral incisor aplasias, implants were placed immediately following the removal of very mobile deciduous teeth. The main reason for this was psychologic.

Four teeth in the mandible (13%) were lost because of trauma. In these patients, it was decided to place the implants precociously. This was to avoid serious bone resorption and to provide an optimal implant position for the prosthetic restoration. In these patients, the implants were placed 2 to 4 months after the teeth had been extracted. Seven teeth in the mandible were lost because of periodontal disease (24%). These patients generally had the most unfavorable prognoses because of the advanced bone resorption, which led to an unfavorable crown/root analogue ratio (C/R ratio).

Presurgical Planning. Two oral surgeons performed the surgical procedures, which were preceded by careful treatment planning together with prosthodontists.[29] An analysis of the position and inclination of the implant was conducted. These 2 parameters, which are of great importance for the final prosthesis, must be considered fundamental, since there are many esthetic and functional factors to be considered when replacing a single tooth in an incisal area. If the implant-abutment interface is positioned incorrectly with regard to the gingival margin, it can lead to esthetic problems that are difficult to solve prosthetically. Also, a poor emergence profile can compromise the patient's oral hygiene and, consequently, the health of the soft tissues around the implants can be negatively affected. Taking all these factors into consideration, meticulous presurgical planning was carried out.

Implant Placement. Brånemark System surgical procedures[6] were followed, with a few exceptions. Surgical access to the implant site in the maxilla was obtained by a midcrestal incision with 1 vertical releasing incision.[30] Other exceptions in implant site preparation were that a pilot drill was not used, and that the final twist drill had a diameter of 2.4 mm. Very few sites needed to be pretapped. All implant placement components were modified to accommodate the 3.0-mm-diameter implants. The number of implants, their positions, and their lengths can be seen in Table 2.

The flaps were sutured without tension using a Supramid (B. Braun/Surgical GmbH, Melsungen, Germany) or GoreTex (3i/Gore, Flagstaff, AZ) suture. The patient was asked to rinse with chlorhexidine twice a day until the sutures were removed 7 days later.

Abutment Connection, Impression Technique, and Prosthetic Treatment. Abutment connections were performed according to standard Brånemark System procedures. To assure the optimal height and modification of the permanent 3.0-mm abutment, healing abutments were used to allow the gingiva to heal before the impressions were made. Once the gingiva had healed, the healing abutment was temporarily removed so that the impression could be made directly on the implant head.[13] Radiographs were taken to confirm the fit between the implant and the impression coping, and the healing abutment was then reinserted while the technician was modifying the final abutment.

The final abutment (designed like the actually marketed Nobel Biocare single-tooth replacement abutment) was placed and tightened, and radiographs were taken to ensure that the optimal connection for the abutment/crown complex had been obtained. In these patients, the abutment screws were tightened by hand, using the clamp on the abutment as countertorque. Thereafter, the crown was cemented, and extra care was taken to remove any excess cement. Often it proved useful to make a supragingival lingual hole in the crown before cementation to allow the release of cement.

All patients received porcelain-fused-to-metal crowns that were cemented to the abutments. Occlusal relationships were accurately checked at the same time that the crown was cemented (Table 3). Static and dynamic occlusal parameters were evaluated during the follow-up visits.

Table 3 Occlusal Relationships

	Yes	No
Contacts in centric relation	26	4
Contacts in protrusion	22	8
Contacts in lateral (right)	12	18
Contacts in lateral (left)	8	22

In this clinical study, the implant lengths were compared with the height of the restorations. The height of the crown was measured from the first incisal contact with the antagonist to the implant/abutment junction, and a C/R ratio was calculated—a parameter that may have a particular meaning for these implant components with a reduced diameter.[31,32] The incisors in the mandible proved to have the most unfavorable C/R ratio. Longer implants might have given a better C/R ratio, but placing longer implants to utilize more mandibular bone would have resulted in a disagreeable lingual hindrance of the restoration for the patient. Therefore, relatively shorter implants were selected so that the buccolingual inclination of the neighboring incisors could be followed with the purpose of obtaining the best shape of the restoration and a good emergence profile. However, this meant greater stress concentration on the components in the mandibular incisors compared to those in the maxilla.

Appropriate distribution of the chewing forces on the anchorage units was considered important. This was achieved by clinically and radiographically verifying a precise fit of the components, an optimal preload of the gold screw, and the crown's design.

The preload is intended as a force, expressed in Ncm, used to close a screw system. In optimal conditions, all of the preload is used to close the system, which is what happens in the single implant situation, where machined components are linked. This can be considered a stress-free situation if the cemented crown is perfectly seated on the single abutment. Unfortunately, when there are uneven contact points on the neighboring teeth, the crown may not be perfectly seated on one side, which could mean a transitional stress situation. In partial prostheses, part of the preload is lost because of the imprecise fit that is always present. This is why prostheses retained with gold screws usually work in non-optimal preload conditions, while in single-implant restorations, the preload can be considered optimal.

Clinical and Radiographic Evaluations. After the prosthetic procedure had been carried out, patients were recalled for clinical follow-up examinations at 1 month, 3 months, and annually thereafter. The parameters checked at these visits were Plaque Index according to Silness and Loë[33] and gingivitis according to Mühlemann and Son.[34] Implant stability, peri-implant conditions, vertical bone loss, and other treatment-related complications, as well as success/survival criteria, were evaluated according to Albrektsson et al.[35]

According to the radiographic technique suggested in the literature,[6,29,36–38] intraoral radiographs of 24 implants (6 radiographs were unreadable) were examined after crown cementation, at 3 months, and at the 1- and 3-year follow-up visits. The distance between the implant-abutment junction, which was taken as a reference point, and the margin of the bone crest was measured. Variations of the bone level for each implant were calculated at the mesial and distal.

Results

Thirty 3.0-mm-diameter implants for single-tooth replacement of lateral incisors in the maxilla (n = 20) and central (n = 9) and lateral (n = 1) incisors in the mandible were placed. All of the 30 implants were placed without any postoperative complications, and the entire healing period was uneventful. All implants were stable at the time of abutment connection, and subsequently all implants were provided with prosthetic restorations. All 30 crowns have been in function and have been followed for a mean period of 63 months (range, 36 to 89 months). However, one failure, a fracture at an implant neck, occurred after about 66 months of function. Thus, the results to date show a cumulative survival rate of 93.3% (Table 4) and an overall survival rate of 96.7%.

Despite the challenging surgery, no symptoms of paresthesia or endodontic problems were reported. No abutment screw loosening was observed, and no clinical symptoms associated with gingival inflammation or fistula formation were reported at the follow-up visits. The plaque and sulcus bleeding indices showed that good oral hygiene has been maintained, resulting in a healthy gingiva.

In many patients a limited amount of bone was present, but this did not influence the stability of the implants. Eight sites of congenital aplasia were noted in the maxillae of 5 patients, resulting in a residual buccal fenestration at implant placement (mean number of exposed threads: 7; SD 3). Only 2 of these 8 fenestrations were covered with bone

Table 4 Implant Survival: Life Table

Time	No. of implants	No. of failures	Not yet due for follow-up	Cumulative survival rate (%)
Implant placement	30	0	0	100
Loaded to 3 years	30	0	0	100
3 to 4 years	30	0	0	100
4 to 5 years	22	0	7	100
5 to 6 years	15	1	4	93.3
6 to 7 years	10	0	5	93.3
7 years	5	—-	—-	—-

Table 5 Marginal Bone Loss During the First Year in Function*

Time	No. of implants
< 1 mm	22
> 1 mm	2
Unreadable	6

*As determined by radiographs. The 2 implants with more than 1 mm of bone loss were in the same patient, and no further bone loss was seen around any of the implants after the first year in function.

chips that were harvested from a special filter device. The other 6 defects were not treated. In the mandible, 4 instances of buccal dehiscences (mean number of exposed threads: 5; SD 1) were recorded. Two were covered with filtered bone chips and the others were left untreated.[28]

In the 4 patients who lost teeth because of trauma, implants were placed approximately 2 to 4 months after the tooth had been extracted. The main reasons for this were to avoid serious bone resorption and to obtain optimal implant position. In the other patients with periodontally compromised tooth extractions, implant placement was performed after a normal healing period of a minimum of 6 months. All sites healed without complications, and the implants were stable.

Despite these particular problems with bone quantity (40% of residual bone defects such as fenestrations or dehiscences), radiographic evaluation revealed only minimal marginal bone loss after 1 year (Table 5). Bone loss of more than 1 mm was found in only one patient (2 sites), where immediate placement was performed and the largest residual fenestration occurred. After the first year of loading, the bone level was stable; ie, no further bone loss was detected.

Complications. One implant that replaced a mandibular central incisor fractured after 5 years in function. After this occurred, the patient refused to appear for recall visits and did not want the complication to be treated in any way.

In another patient, a relevant complication was permanent dislocation of the abutment/crown complex of a mandibular central incisor, which had the most unfavorable C/R ratio resulting from previous tissue loss. After 1 year in stable function, the patient suddenly experienced pain upon incising. The crown remained immobile but seemed to be dislocated labially (Fig 2a). The crown had lost contact with the neighboring teeth, but the abutment screw remained tight and was not deformed. The crown was subsequently removed using a lingual hole, the abutment was unscrewed, and another impression was made to prepare a new restoration. After having eliminated the traumatic occlusal contacts, the original abutment/crown complex was used as an interim crown until a new abutment was seated and a new crown was cemented. No further complications were seen in this patient during the following 4 years (Figs 2b and 2c).

Discussion

Judging from the clinical results of this study, using implants and abutments that are narrower than the standard components seems to be a good treatment option for single-tooth restorations when replacing small incisors. Only 2 complications occurred during the follow-up period, and compared to earlier studies of single-tooth replacement,[13] in which abutment screw loosening (titanium screws) was a major problem, this study clearly shows that this problem has been overcome, since no gold abutment screws loosened. Minimal marginal bone loss was recorded, despite the fact that the implants were often placed

Fig 2a A permanent buccal dislocation of a mandibular abutment/crown complex occurred in an older male patient. The crown remained immobile but had lost contact with the neighboring teeth.

Fig 2b Clinical view of new mandibular crown in place. Despite the dislocation of the original crown, the implant had remained stable, so a new abutment could be seated and a new crown was placed.

in areas with a limited amount of bone, which in some instances led to residual bone defects.[28] One important factor that might explain these favorable results could be the presence of light occlusal forces in the regions of the incisor dentition.

In many of the mandibular single-tooth replacements in this study, the C/R ratio was not favorable. The height of the crown/abutment complex was higher than the implant length, which could be a negative factor, if the reduced strength of these smaller implants is considered. Therefore, only limited indications were chosen for this study.

Mechanical considerations are always important issues in treatment planning. The difficulty of an in vivo analysis of the load on the bone in the implant area, because of the great number of variables that can influence it, suggests a simplified approach to the problem. In osseointegrated screw-type implants, the distribution of chewing loads occurs if there is a vertical load along the threads of the implant. The load is registered by compression load in the bone. In instances of lateral load, the transverse force causes bending movements on the crown/abutment/implant complex, which can cause fatigue of the implant.[32,39–41]

Since the resistance of smaller-diameter implants to fatigue is reduced, further investigation is needed to determine the best clinical usage of these implants. The Brånemark System concept is that the weakest part of the prosthesis must be situated on components that can easily be substituted, ie, on the gold screw or abutment screw—not on the implant. Since overloading may challenge the biomechanical and engineering factors, it is obvious that a reduction in the width of the implant may

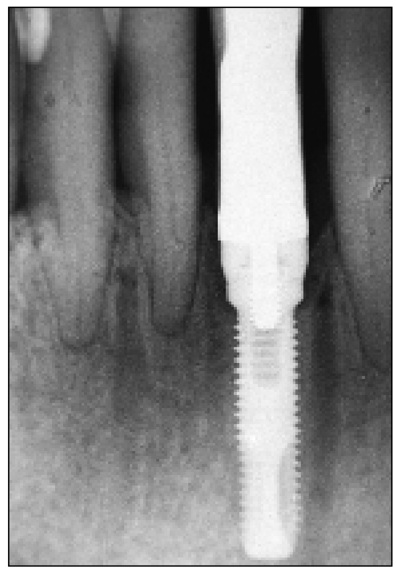

Fig 2c Radiograph of the new mandibular implant/abutment/crown interface, which has been in place for more than 4 years. The radiograph clearly shows the reduced periodontal support of the neighboring teeth, which could explain why the original crown became overloaded and dislocated. This choice of treatment can be debated, since there were other treatment options that might have seemed more appropriate at the time. The major reason for choosing implant treatment was that this was what the patient wanted. This treatment has also proven to be beneficial if one considers the fact that before treatment all other incisors presented a grade 2 mobility, and that the actual mobility of the neighboring teeth after 6 years of treatment was no more than grade 1.

cause it to become the weakest component in the anchorage unit. Since orthodontic movements of neighboring teeth can affect the load situation on single implants, this may have been the cause of the crown dislocation reported in one patient. Therefore, it is suggested that the previous statements be carefully evaluated before functional loading. This may only be speculation, since the width of the abutment screw for this narrower implant is also reduced in diameter, and this could prevent the overload from being transferred to the implant.

Conclusion

Even if the favorable clinical results obtained using these narrow 3.0-mm-diameter components seem to confirm the predictability of replacing small incisors, the indication must be limited to select cases where light occlusal forces are anticipated. In this patient series, the relative overload causing complications occurred in the 2 oldest patients. Both of these patients had a history of periodontitis. Furthermore, both of these patients were affected by severe reduction of periodontal support of the neighboring lower incisors, which resulted in the replaced tooth being the only stable one, ie, the prosthetic restoration was subjected to the largest load/force. With a stronger narrow implant that has the same emergence profile, and with the same surface structure and materials as the original Brånemark System implants, these patients could probably receive much safer and more predictable treatment.

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