Clinical Outcome and Prosthodontic Compensation of Tilted Interforaminal Implants for Mandibular Overdentures

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Purpose: *The aim of this study was to evaluate the sagittal inclination of interforaminal implants, the clinical implant outcome, and the necessary extent of prosthodontic compensation modalities for implant overdentures (IODs).* ***Materials and Methods:*** *Lateral cephalometric radiographs of 62 patients, each with a mandibular IOD retained by 2 to 4 implants, were analyzed. The sagittal inclination of the longitudinal implant axis of the most anterior implant was analyzed relative to the mandibular and occlusal planes. The angle needed to compensate for the inclination of the mandibular implant to obtain Angle's class I for the prosthesis (the compensation angle) was measured and compared with respect to skeletal class. Peri-implant structures were measured using the Plaque Index and the Gingival Index. The compensation angle was correlated with the mandibular implant inclination, the degree of mandibular atrophy, and the anterior facial height.* ***Results:*** *The most anterior mandibular implants showed a mean retroinclination of 74.3 ± 9.3 degrees in relation to the mandibular plane; retroinclination was significantly more pronounced in skeletal class II than skeletal classes I and III (*$P < .05$*). The compensation angle (26.9 ± 10.5 degrees) was more significant for skeletal class II than for skeletal classes I and III (*$P < .01$*). Sagittal mandibular implant inclination correlated significantly to the compensation angle (*$r = -0.46$*; $P < .05$*), mandibular atrophy (*$r = 0.32$*; $P < .05$*) and mandibular facial height (*$r = -0.45$*; $P < .05$*). Implant survival rate and peri-implant parameters (bone loss, pocket-depth, Plaque and Gingival Indices) of the interforaminal implants were not shown to be influenced by implant retroinclination. Nine patients (2 skeletal class 1, 7 skeletal class II) reported phonetic problems with the IOD because of narrowing of the lingual space but described significant improvement after a median 4.7 months (range, 3 to 12 months).* ***Discussion and Conclusion:*** *Depending on skeletal class, prosthetic compensatory mechanisms will be operative in the presence of mandibular implant retroinclination for IOD. Knowledge of mandibular inclinations and the compensatory mechanisms may be an essential factor in successful prosthetic rehabilitation and may provide for a homogenous design of the bar construction and easier handling and may also reduce stress on the attachment mechanism.* Int J Oral Maxillofac Implants 2005;20:923–929

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Implant-supported restoration of the edentulous mandible has become a standardized and well-proven treatment approach over the last 3 decades.[1–3] Numerous studies have reported on the subjective and objective satisfaction with prosthetic retention and the restored masticatory comfort obtained with implant-retained mandibular overdentures (IODs).[4,5] Regardless of the number/type of implants used or the design of the retention elements, long-term follow-up investigations of edentulous patients treated with IOD have shown a high success rate.[4–8]

To ensure optimal outcome and long-term survival of dental implants, it is usually recommended

that the implant axis be perpendicular to the occlusal plane and simulate the axis of natural teeth.[9–11] However, the placement of interforaminal implants must also take into account the compromised morphology of the edentulous mandible. According to anatomic findings, deviations from the proposed perpendicular implant axis are required for implant placement.[11–14] In a study by Mericske-Stern,[15] an exactly perpendicular position could only be found in a small percentage of patients, while most patients showed a lingual or buccal deviation of the interforaminal implant axis. Such inclination may lead to prosthodontic complications as a result of the fabrication of the connected superstructure or even when individual attachments are used. When using single retentive modalities, such sagittal deviations may result in an increased prosthetic complication rate.[16]

Human cephalometric radiographs characteristically show an angle of 90 to 95 degrees between the mandibular plane and the dental axis of the mandibular incisors.[17,18] As a result of ongoing mandibular atrophy, the remaining bone does not reveal its maximum diameter in the direction of the axial position of the natural tooth; instead, it appears to be retroinclined.[19,20] This atrophy is associated with a modified morphology for the placement of anterior implants in the interforaminal region, which frequently causes a lingual inclination of implants.[15] Placement of implants with a sagittal retroinclination with respect to the mandibular plane requires the fabricated superstructure to compensate for the nonanatomic position of the mandibular incisor implant to adequately meet functional and esthetic expectations.[19,20] Apart from the inclination of the longitudinal implant axis with respect to the occlusal plane, which should influence implant prognosis, the sagittal inclination of the longitudinal implant axis to the mandibular plane (mandibular inclination) is therefore of particular prosthetic importance.

There is a lack of information in the international literature regarding the extent of the possible inclination of interforaminal implants in the sagittal plane.[15,16] There are some rare reports on the clinical results of tilted interforaminal implants but no information on the need for and the necessary extent of appropriate prosthodontic compensation modalities used to obtain satisfactory esthetic and functional results.[20–25]

The aim of the present study was to examine the extent of interforaminal sagittal implant inclination, especially with respect to the occlusal and the mandibular planes. Interest was also focused on clinical results of the inclined implants, on the periimplant structures, and on the potential therapeutic options for prosthodontic compensation in different skeletal classes.

MATERIALS AND METHODS

Sixty-two patients (64.2 ± 11.3 years) with an edentulous mandible were included in this study. Two-hundred twenty-six implants (2 to 4 per patient) including 114 Brånemark System implants (Nobel Biocare, Göteborg, Sweden; 31 patients), 36 Frialoc implants (Friadent, Mannheim, Germany; 9 patients), and 76 Camlog implants (Alltec, Wurmberg, Germany; 22 patients) were placed in the patients' mandibles, and bar-retained mandibular IODs were fabricated. Treatment of the patients' maxillae involved either conventional complete dentures (n = 56) or implant-retained complete prostheses (n = 6). All complete maxillary prostheses (n = 62) were newly fabricated in the course of fabrication of the mandibular prostheses.

For the subsequent prosthetic analyses, lateral cephalometric radiographs (Fig 1) were taken and traced for all patients. Radiographs were traced and measured according to orthodontic guidelines.[17,18] Tooth positioning for the maxillary prosthesis and thus location and position of the maxillary incisor was determined by prosthodontic principles and according to individualized esthetic requirements. The esthetic line (nose tip to chin) was not supposed to be more than 4 mm from the lower lip. Subsequently, the position and inclination of the newly determined prosthetic mandibular incisor tip was determined according to the position of the maxillary incisor. For all patients an Angle's class I relationship was prosthetically established (Fig 1).

The skeletal relationship was determined using the facial plane angle, ie, the angle between the facial planes and the Frankfort horizontal (90 degrees ± 3 degrees) plane. Skeletal class I (harmonic mandibular relation) required a facial plane angle of 87 to 93 degrees; class II (retromandibularism) required an angle of less than 87 degrees; and class III (antemandibulism) required an angle of greater than 93 degrees (Fig 1).[17,18,26,27] The angle between the anterior nasal spine and the D point (center of symphysis)—the X_i point—determined the (mandibular) anterior facial height; an angle of 50 degrees (± 4) was considered standard (Fig 1).

The mandibular plane served as a reference for determining the sagittal mandibular inclination (SMI) of the longitudinal implant axis of the most anterior implant (with analogous measurement of the natural mandibular incisor; Fig 2). The sagittal inclination of the implants was also measured with respect to the occlusal plane; thus, the facial and lingual inclinations of the implants were also evaluated. For the various skeletal classes the SMI of the implants was compared. Planes defining the height of the symph-

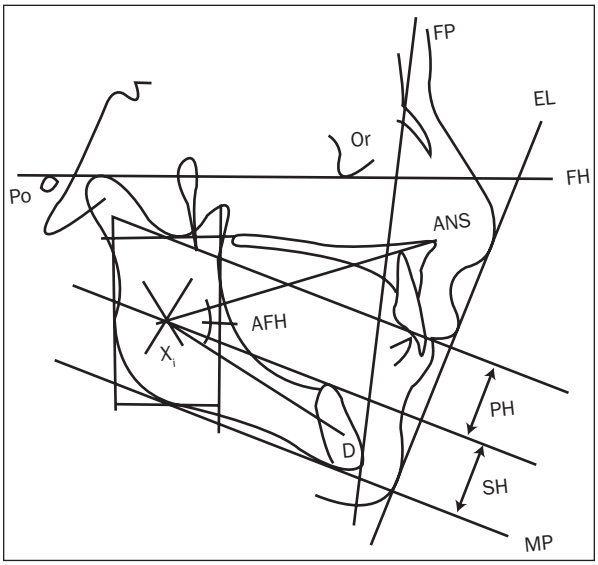

Fig 1 Cephalometric landmarks. Po = porion; Or = orbitale; ANS = anterior nasal spine; FH = Frankfort horizontal; FP = facial plane; MP = mandibular plane; D = point D (center of symphysis); X_i = point X_i; AFH = anterior facial height; SH = symphyseal height; PH = prosthetic height; EL = esthetic line.

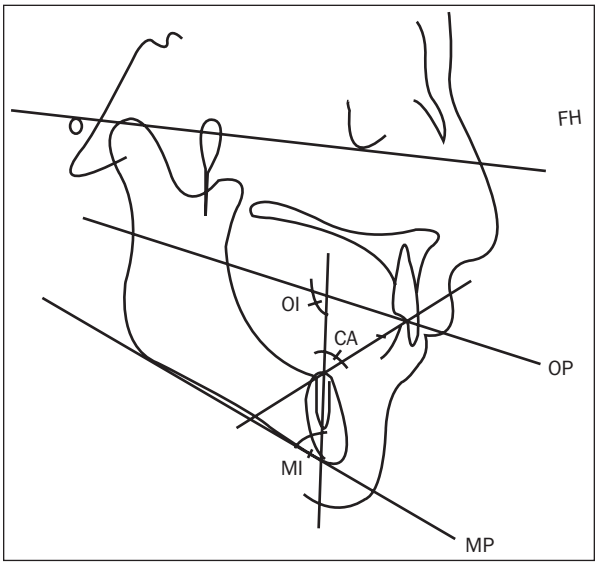

Fig 2 Landmarks for determination of the sagittal mandibular inclination of the longitudinal implant axis of the most anterior implant and the prosthodontic compensation angle. MP = mandibular plane; MI = (sagittal) mandibular implant inclination; OP = occlusal plane; OI = (sagittal) occlusal inclination; CA = compensation angle; FH = Frankfort horizontal.

ysis (SH) and the height of the prosthetic suprastructure (PH) were traced. The degree of mandibular atrophy was determined using the relation between bone (symphyseal) height (SH) and PH (Fig 1).

The central exit point of the most anterior mandibular implant and the prosthetically determined mandibular incisor tip was defined as the "prosthodontic compensation axis." The angle between the longitudinal implant axis and the compensation axis was defined as the prosthodontic compensation angle (PCA), ie, the angle required to compensate inclination of the mandibular implants so as to obtain establish a class I occlusal relationship (Fig 2). The PCA was compared between the individual skeletal classes and correlated with variables such as implant SMI, degree of mandibular atrophy, and anterior facial height.

Follow-up evaluation included the survival of the implants, the survival (success) of the IODs, and especially peri-implant bone loss (mm), pocket depth (mm), and peri-implant soft tissue characteristics. Radiographic bone loss was determined using an orthopantomogram and/or radiographs based on the paralleling technique and comparing the primary postoperative radiograph with the most recent one. Mesial, distal, lingual, and buccal pocket depth were measured using a calibrated periodontal probe (Hu-Friedy, Chicago, IL). Gingival evaluation followed a modified Gingival Index (0 = no inflammation; 1 = slight inflammation; 2 = moderate inflammation; 3 = severe inflammation).[28,29] Plaque Index (0 = no plaque; 1 = plaque in the apical third of the crown, 2 = plaque in the middle third of the crown; 3 = plaque in the coronal third of the crown) was also assessed.[28,29]

In addition, all patients were questioned about specific prosthetic problems (narrowing of lingual space, phonetic problems, masticatory/swallowing problems) and assessed subjectively on a scale ranging from 1 (no problems at all) to 5 (severe problems) initially and at 3-month intervals for a period of 1 year.

Mean values were compared using the Student *t* test; correlations were tested with the Spearman rank test. $P < .05$ was taken as the statistical significance level.

RESULTS

All patients had prosthetic restoration of the lower facial height within the standard range indicated (48.3 ± 4.5 degrees) and restoration to a class I occlusal relationship. Cephalometric analyses revealed 37 patients (60%) as skeletal class I, 14 patients (22%) as skeletal class II, and 11 patients (18%) as skeletal class III.

Sagittal implant inclination with respect to the occlusal plane (occlusal inclination) varied between 81 and 107 degrees, with a median value of 95.8 ± 9.5 degrees. Forty-three patients (70%) had occlusal inclinations in a lingual direction (> 90 degrees),

Table 1 SMI and PCA in Different Skeletal Classes

	SMI		PCA	
	Mean ± SD	Range	Mean ± SD	Range
Class I	73.2 ± 9.4	53–96	24.5 ± 7.2	8–40
Class II	68.3 ± 9.1	67–92	33.8 ± 12.3	5–52
Class III	81.3 ± 9.7	53–93	22.5 ± 11.9	12–43
Total	74.3 ± 9.3	53–96	26.9 ± 10.5	5–52

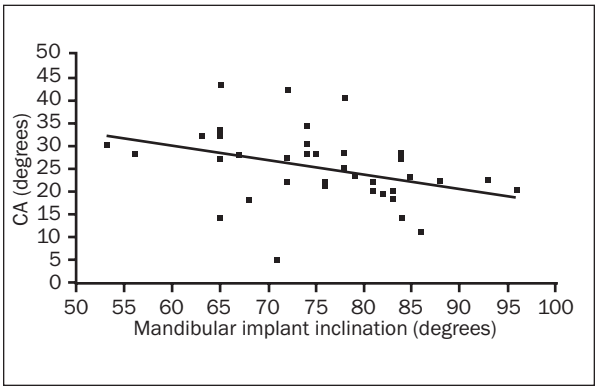

Fig 3 *(Right)* Correlation between SMI and PCA.

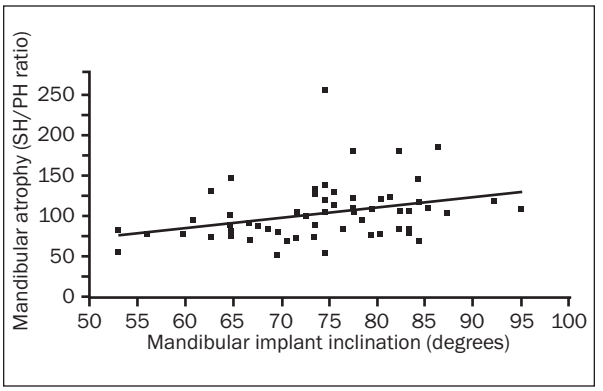

Fig 4 Correlation between SMI and degree of mandibular atrophy (SH/PH ratio).

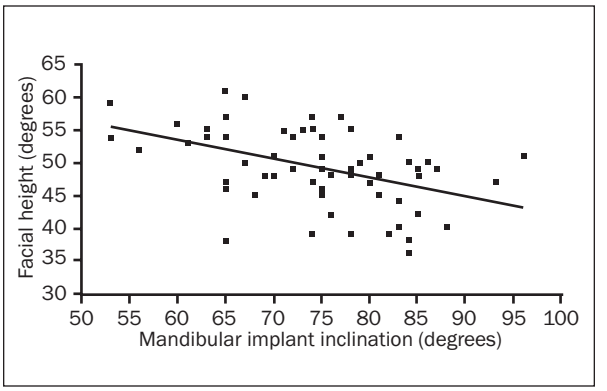

Fig 5 Correlation between SMI and mandibular facial height.

Table 2 Soft TIssue Characteristics of the Implants (n = 226)

	Plaque Index		Gingival Index	
	n	%	n	%
Grade 0	64	28.7	121	53.5
Grade 1	132	58.4	84	37.1
Grade 2	29	12.8	21	9.3
Grade 3	0	0	0	0

while 19 patients (30%) showed an inclination in facial direction (< 90 degrees).

In relation to the mandibular plane (SMI), the most anterior mandibular implants showed a median retroinclination of 74.3 ± 9.3 degrees. The mandibular implant inclination varied significantly ($P < .01$) between the different skeletal classes, with skeletal class II showing a significantly more pronounced retroinclination than skeletal classes I and III (Table 1).

Table 1 also shows the compensation angles (CA) required to achieve class I occlusion. The compensation angle was more significant for skeletal class II than for skeletal classes I and III ($P < .01$). There was a significant correlation between SMI and CA ($r = –.46$, $P < .05$; Fig 3). SMI was significantly correlated with the degree of mandibular atrophy ($r = 0.32$, $P < .05$; Fig 4) and also with mandibular facial height ($r = –.45$, $P < .05$; Fig 5). The higher the retroinclination of the implants was, the more pronounced the compensation with CA and by possible verticalization measures became.

During the follow-up period (43.8 ± 12.5 months) no implant loss was observed, resulting in an implant survival rate of 100%. None of the IODs were lost (success rate of 100%). However, a number of prosthodontic modifications were required (rebasing in 6 cases, teeth fracture 11 in cases, clip/ball activation in 11 cases).

Mean bone resorption was found to be 2.1 ± 1.7 mm (range, 0 to 4 mm). Mean pocket depth was 3.8 ± 1.6 mm (range, 0 to 5 mm). Plaque and Gingival Index scores are shown in Table 2. The peri-implant parameters and the IOD results found in this study were similar to data previously reported in the literature.[1,2,5–8,23] No differences between the various implant types and implant lengths were found.

In the follow-up, 9 patients (2 with skeletal class I, 7 with skeletal class II [retromandibulism]) reported problems with the IOD initially. They were initially rated with a mean subjective score of 3.2 ± 0.5. In particular, these problems included narrowing of lin-

gual space and phonetic problems, which improved after a median 4.7 months (range, 3 to 12 months) to a mean score of 1.5 ± 0.4 ($P < .05$). Seven of the 14 patients (64%) with retromandibulism (skeletal class II) reported initial lingual problems.

DISCUSSION

For ensuring a successful long-term implant prognosis, clinicians are advised to place implants parallel to each other and perpendicular to the occlusal plane. Although there is a paucity of clinical investigations on this topic, the importance of the implant angles/inclinations has been emphasized in a few studies.[15,16] The methods used in studies investigating implant inclination have been associated with certain flaws, because the studies rarely describe exactly how angles/inclinations were measured or whether they contributed to prosthetic problems, especially with respect to IODs.[15,16] In a recent study by Walton and Peck,[16] the long axis was measured using digital photography, and measurements showed that implant deviations were less marked when implant placement was done by experienced surgeons than when it was done by inexperienced surgeons.

In the present study, not only did the authors calculate the inclination relative to the occlusal plane, they also attempted to illustrate the deviation of anterior mandibular implants from the physiologic position of mandibular incisors with regard to the mandibular plane. It is technically rather easy to place interforaminal implants parallel with respect to the frontal plane and also with respect to the hinge axis.[15,16] However, the position in the sagittal plane significantly depends on the degree of atrophy, so placement perpendicular to the occlusal plane or in the direction of the physiologic position of the mandibular incisors is frequently impossible or only partly possible.[15,19,20] Attempting to achieve placement perpendicular to the occlusal plane will frequently necessitate placement in a more distal location depending on the degree of atrophy and the available bone. As a result, the imaginary line connecting the interforaminal implants will come to lie significantly farther lingual. This may be unproblematic when using single prosthetic attachments, but may cause problems when using connected bar structures.[16–23,25]

The present investigation focused on the sagittal inclination of interforaminal implants with respect to the mandibular plane and their influence on the prosthodontic outcome. Although inclination of the implants with respect to the occlusal plane provided for a favorable position with regard to implant prognosis,[21–24] the present study showed that the available bone situation required implant placement with mandibular retroinclination. A potential advantage of implant placement with mandibular retroinclination is the availability of an adequate bone supply and optimal peri-implant closure with a keratinized mucosa.[29,30] If the inclination of anterior implants needed to be consistent with that of the mandibular incisors, length of the implants would possibly need to be reduced, and peri-implant mucosa closure likely would not be possible.

However, if optimal prosthetic results are to be ensured, such implant positioning may require compensatory mechanisms in the fabrication of the superstructure.[16,17,20–24,30] Retroinclination of the anterior implants is in obvious contrast to the position of the natural mandibular incisors but induced by mandibular atrophy. The present results demonstrate that a satisfactory prosthodontic compensation could invariably be achieved in spite of implant retroinclination by subsequent anteversion of the mandibular prosthodontic incisors and adequate verticalization of the prostheses. The results demonstrate that the extent of the required prosthetic compensation is indicated by the CA. The PCA was significantly higher for patients in skeletal class II.

As a matter of physiologic dimension and as shown by the results of this study, measurement of the sagittal implant inclination with respect to the mandibular plane appears to be more relevant for optimal prosthodontic rehabilitation with IOD than calculation of the implant inclination with respect to the occlusal plane.[15,16] It is a well known fact that posterior skeletal changes in the mandible may cause variations in the occlusal plane and thus result in diverging values for the implant inclinations indicated.[31-34] In obvious contrast, the mandibular plane has been shown to be unaffected by resorption processes and is considered a stable reference point.[16,32,33] Overall, it appears meaningful to adequately consider both inclination angles, though in different ways. Thus, mandibular inclination with its associated compensation mechanisms and angles may be of specific importance regarding prosthetics, and occlusal inclination may be of particular relevance for implant prognosis and calculation of occlusal forces.[12,13,16–20]

It appears meaningful to obtain preoperative cephalographic data of mandibular morphology and to conduct exact and careful prosthetic planning prior to implant placement.[16] Obtaining such diagnostic findings may be especially helpful and beneficial for patients with skeletal class II. In cases of doubt among patients with skeletal class II, retroincli-

nation of the implants and of the attached prosthesis may increase the posterior position of the mandible. Retro-planning targeted to ensure ideal preoperative definition of the mandibular implant inclination appears to be meaningful for the success of optimal prosthetic rehabilitation, including utilization of all compensation options.

Numerous reports have indicated no significant changes in bone loss or peri-implant situation associated with abutment inclinations or with implants tilted with respect to the occlusal plane.[35–40] Results for the retroinclined interforaminal implants in the present study did not differ from overall data in literature.[1,2,5–8,23,41] These results concerning the nonaxial loading of implants are confirmed by the results for interforaminal implants described by Haas and coworkers.[37] It can be concluded that tilting, and especially retroinclining of interforminal implants, and nonaxial loading with regard to the occlusal plane has no impact on these outcomes for interforaminal implants.[1,2,5–8,35–39] Therefore, departure from the planned perpendicular placement relative to the occlusal plane should be considered when placing interforaminal implants; the sagittal inclination with respect to the mandibular plane and desired correction angle should be considered as a more important factor.[15,41] Depending on the skeletal class, prosthetic compensation mechanisms will come to bear in the presence of retroinclination.[16] Moreover, in the present study, clinical follow-up revealed that retroinclination caused no persistent subjective problems.[16,33–40] Nevertheless, initial and long-term success of prosthetic rehabilitation with IODs was predominantly achieved because a satisfactory lingual situation was achieved.[1,2,12,39,40]

CONCLUSION

Sagittal mandibular inclination should be attributed more importance than axial loading of the implants. A more facial inclination may not only provide for a more homogenous design of the bar construction but also for easier placement and removal of the IOD and thus produce less stress on the attachment mechanism.[16,30,31] Basic knowledge of potential mandibular inclination and the necessary compensatory mechanisms may be an essential factor in the success of prosthetic rehabilitation. As regards implant prosthodontics, interforaminal implant inclination with respect to the mandibular plane certainly is a more important aspect than implant inclination with respect to the occlusal plane.

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