Axial Relationship Between Dental Implants and Teeth/Implants: A Radiographic Study

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The relationship of dental implants with neighboring teeth will affect both occlusal relationship and distribution of forces; thus, the purpose of this study was to examine implants' axial relationship with adjacent and opposing teeth/implants. Data of dental implants patients was retrieved. Panoramic X rays were digitized. Computer-based software was used to measure the angular relationship between the implants and adjacent/opposing teeth and implants. Data was further sorted by the mode of placement and implants position. 50 patients (219 implants) were included. Mean angle to adjacent tooth/implant was 178.71° ± 9.18° (range 129.7°–206°). Implants were more parallel to adjacent teeth (180.99° ± 1.06°) than to adjacent implants (176.32° ± 0.54°; $P = .0001$). Mean angular relationship to opposite tooth was 167.88° ± 8.92° (range 137.7°–179.8°). Implants that were placed freehand or with positional guide had similar intra-arch relationship (178.22° and 178.81°, respectively) and similar inter-arch angulations (164.46° and 167.74°). Molars had greater deviation of the angular relationship (175.54°) compared to premolars (181.62°) and incisors (180.55°, $P = .0001$). Implants placed in the maxilla had smaller axial deviation compared to implants in the mandible (180.41° ± 0.64 vs 177.14° ± 1.02; $P = .0081$). Good axial relationship may be obtained in most implants placed by an experienced clinician, even when placed freehand. The mandibular posterior region is more prone to axial deviation and as such requires special attention.

Key Words: dental implants, inclination, angulations, guides, stents, freehand

INTRODUCTION

Correct implant placement involves complex biological and mechanical factors that must be considered for optimal implant success. Implant placement is a key factor in achieving satisfactory esthetics, a harmonious occlusion, and peri-implant health.[1] Pellizzer et al[2] have recently shown in a photoelastic analysis of stress distribution that the greater the angulation of an implant, the higher the stress it exerts on the cervical bone adjacent to the implant. The excessive occlusal forces that may result from unfavorable implant placement may cause marginal bone loss, implant or superstructure mechanical failure, or even complete loss of osseointegration.[3–5] Implant axial angulation should be designed to allow prosthetic reconstruction that will direct the occlusal forces vertically.

Perfect alignment is not always attainable due to anatomic limitations that hinder optimal position, such as limited inter-arch clearance that hinders the maneuverability of the surgeon, especially in posterior areas.[6] Other operative factors that have been found to influence the mesiodistal implant angulation include the experience level of the surgeon, drilling speed, and the rate of increase in drilling diamete.[7]

To achieve the desirable implant position, a

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variety of surgical stents are sometimes used. These in general are categorized into *positional guides* (that dictate only the appropriate mesiodistal and buccolingual emergence position of the implants) and *axial guides* (that also dictate the osteotom and implants angular direction). Naitoh et al,[8] using an axial surgical guide, have reported mean 5 degree (0.5°–14.5° range) between the planned and actual angulation of the implant. Likewise, Arisan et al[9] have recently reported that stereolitographic guidance systems have mean deviation of 5.0° ± 1.6° when bone support is used while 2.9° ± 0.4° when mucosal support was used. Positional guides (sometimes referred to as "prosthetic stents") were also reported to have good results. Talwar et al[10] have recently reported favorable results when acrylic positional guide were used in conjunction with 3D CT images.

Nonetheless, more often than not, dental implants are placed freehand without the use of any guidance or positional guides. This is due in part to some of the drawbacks associated with these devices, including cost, additional radiation, and the overall more complicated surgical procedure.

The aim of the present study is to measure the actual implant angulations and parallelism to adjacent teeth/implants in the same arch and its relationship to opposing teeth when placed freehand or in conjunction with positional guide.

Materials & Methods

For the purpose of this retrospective study, data of patients who were treated using dental implants in the Department of Periodontology, School of Graduate Dentistry in the years 2007–2008, was retrieved from the medical files. All these implants were placed by the same surgeon (EEM) with more than 25 years' experience with implants placement. Implants were placed freehand or with the aid of an Omnivac guide (teeth–tissue supported) with occlusal marking of the preferred implants location.

Cases were included only if they had a postop panoramic radiographs. Cases were excluded in the absence of a neighboring tooth or an implant adjacent to the experimental implant or if the neighboring teeth were misaligned.

Following demographic and surgical data acquisition, all panoramic X rays were retrieved, digitized (Powerlook 1000, HP Dhal Software, Viewbox 3.1, Cephalometric, Kifissia, Greece) and stored. Next, using computer-based software (Viewbox 3.1, Cephalometric Software, dHAL Software, Kifissia), the following parameters were measured on these images (Figures 1 and 2):

1. The angular relationship between the vertical axes of the implants and the vertical axes of the adjacent teeth.
2. The angular relationship between the vertical axes of two adjacent implants (when more than one implant was inserted).
3. The angular relationship between the vertical axes of the implants to that of the opposite teeth/implants.

Data was further sorted as per the mode of placement (ie, freehand or with a positional guide) and implants position (ie, molar versus premolar or incisor position and maxilla vs the mandible).

Statistical analysis

Unpaired Student *t* test was used to compare implants angle with and without surgical guide. Analysis of variance (ANOVA) with Scheffe's modification was used to compare these angular relationships between the different placement area (molar, premolars, and incisors). A 5% significance level was used.

Results

Included in this study were 219 implants in 50 patients (18 male, 32 female); patient and implant characteristics are described in Table 1. Mean age was 54.67 ± 10.49 years (range 17–79 years). These implants were evenly distributed between arches (114 maxillary and 105 mandibular) and were mainly positioned in posterior regions (110 molars, 68 premolars, and only 41 incisors). Most of the implants were standard diameter implants, 10–16 mm long (11.5 mm median length, 3.75 median diameter).

The mean angular relationships between these implants and adjacent/opposing teeth or implants are presented in Table 2. Overall, the mean angle to adjacent tooth/implant was 178.71° ± 9.18°; however, some implants were placed in more extreme angles, as can be seen from the ranges for individual sites (129.7°–206°). Implants were more

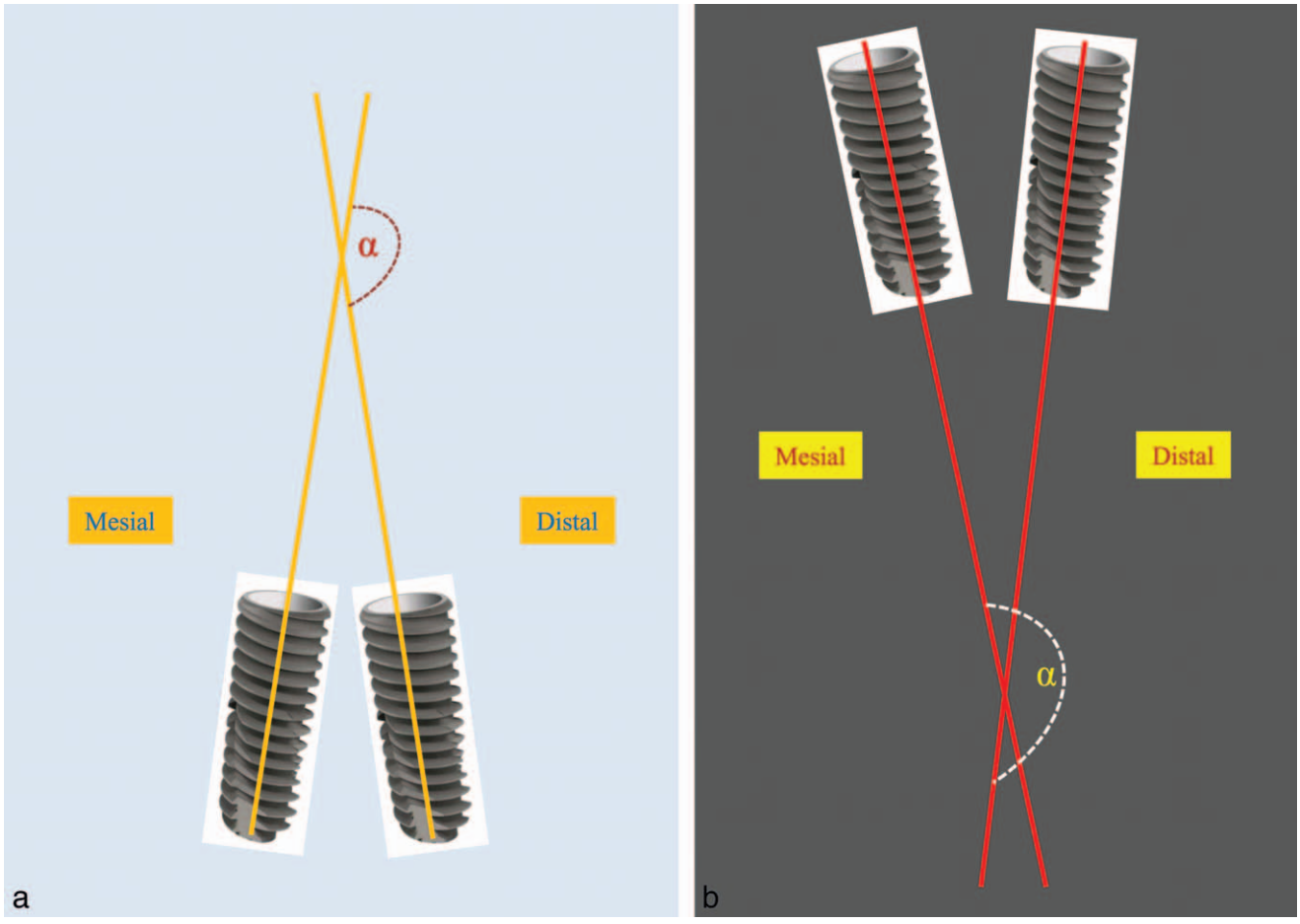

Figure 1. The axial relationship between two neighboring implants was measured and expressed in degrees (α angle). (a) When the two structures were converging toward each other, an angle smaller than 180° was measured. (b) When the two structures were diverging from one another, these measurements were greater than 180°.

significantly parallel to adjacent teeth (180.99° ± 1.06°) than to adjacent implants (176.32° ± 0.54°); these differences were also statistically significant ($P = .0001$). The mean angular relationship of implants to opposite teeth was 167.88° ± 8.92°, with a range of 137.7°–179.8°.

When these angular relationships were compared vis-a-vis the utilization of positional guide during surgery (Table 3), there was no difference between these two placement modes in relation to intra-arch (178.22° ± 1.1° vs 178.81° ± 0.7°) and inter-arch (164.46° ± 1.6° vs 167.74° ± 0.8°) measurements for implants placed with or without stents, respectively.

Table 4 presents the effect of implants location on its angular relationship. Molars had greater divergence of the angular relationship from neighboring teeth (175.54° ± 1.07 [SE]) compared to premolars (181.62° ± 0.79 [SE]) and incisors (180.55° ± 1.1 [SE]). These differences were statistically significant ($p = 0.0001$). Likewise, implants placed in the maxilla had much smaller deviation from the neighboring compared to implants in the mandible (180.41° ± 0.64° vs 177.14° ± 1.02°; $P = .0081$).

Discussion

In the present study, dental implants performed by a trained surgeon in general were well aligned to each other (mean 176.33° ± 5.54°) and to neighboring teeth (180.99° ± 11.21°). These mean deviation of +0.99° to −3.67° from perfect parallelism is relatively very small. Horwitz et al[11] have compared in vitro using a 3D analysis, the angular deviation between planned and actual implant position using a CT guided placement template. The mean discrepancy between the two positions was reported to be very similar (0.5°–4.7°). Likewise,

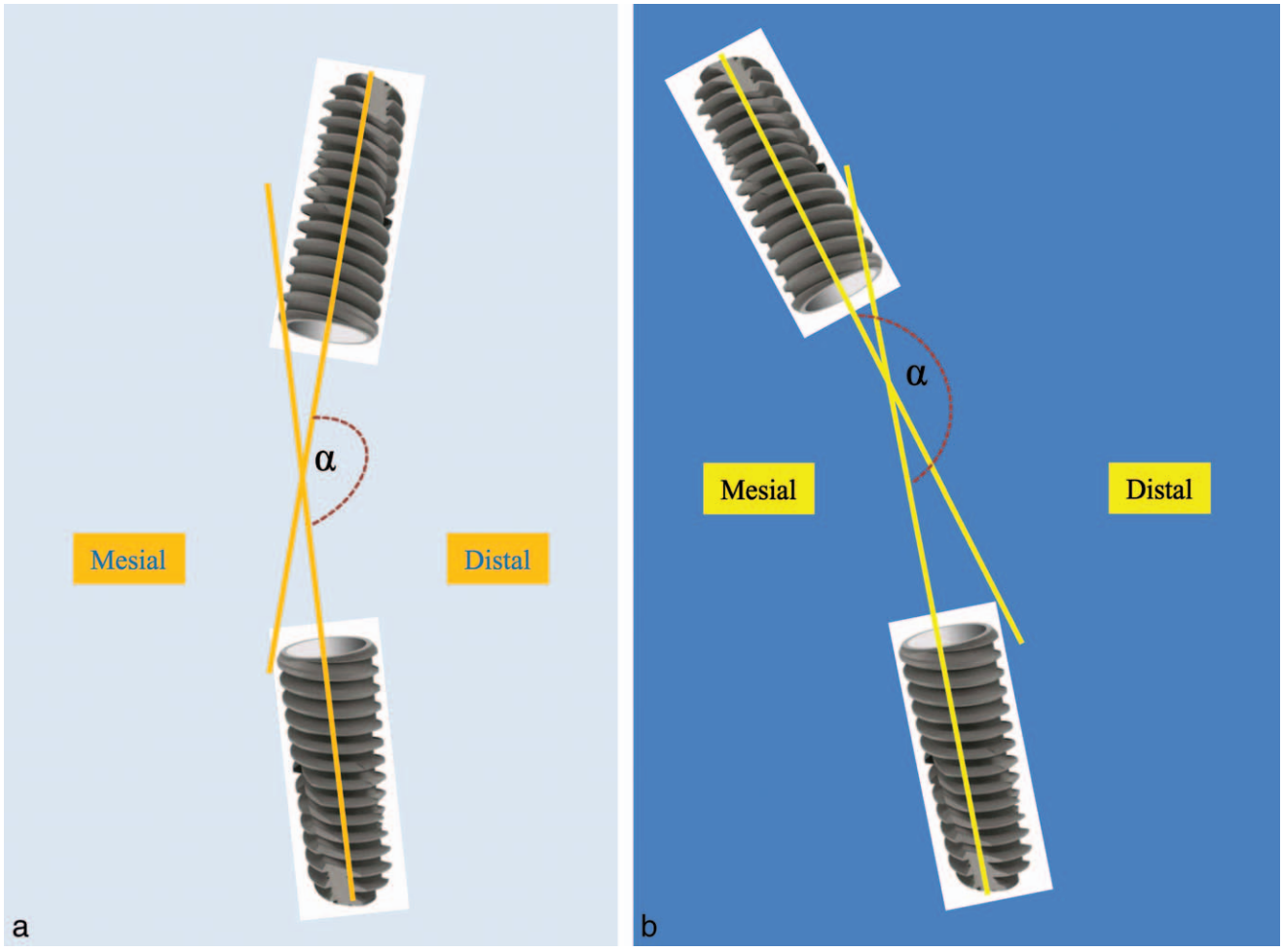

Figure 2. The axial relationship between two opposing implants (α angle). (a) When upper implant is inclined mesially, an angle smaller than 180° was measured. (b) When the upper implant is inclined distally, these measurements were greater than 180°.

Hinckfuss et al[12] have compared the actual versus planned axial angulation of dental implants in an in vivo study. They reported mean absolute angle error for all guides to be 1.61° and 2.39° (mesiodistal and buccal-lingual angulations, respectively) with an overall range of 0.01° to 9.7°. This relatively good axial relationship may be related to operator experience. Walton et al[13] were able to show that less experienced surgeons had a significant greater tendency to place implants that diverged from each other in the frontal plane and with a facial or lingual inclination in the sagittal plane. Similarly, in a study of the surgical parameters that affects implants axial inclination, Payer et al[7] reported that experienced surgeons had smaller deviation compared to novice clinicians.

Despite the overall good results, some implants were placed in significant mesio and distal angulation (ranging from 129° to 206°). This deviation may be associated with individual patient related factors such as small interarch distance, intra-operative discomfort and cooperation and/or site-related factors such as crowding, tilted teeth, drilling method, and intentional angulation to avoid anatomical structures.[14]

Implants placed in the mandible had slightly lesser favorable alignment with the neighboring teeth (177.14° ± 1.02°) compared to those in the maxilla (180.41° ± 0.64°; $P = .0081$). These should probably be attributed to the implants in the posterior mandible, which are more difficult to handle: buccal soft tissues limit access and restrict the field of vision; in addition, smaller interarch distance in this region significantly affects our ability to properly place the surgical drill. It has been reported that the average angular divergence

Table 1

Patient and implant characteristics

No. of patients	50
Female	32
Males	18
Mean age (years)	54.67 ± 10.49
Range	19–79
No. of implants	219
Implants per arch	
Maxilla	114
Mandible	105
Implants by region	
Incisors	41
Premolars	68
Molars	110
Diameter (mm)	
Mean	3.72
Median	3.75
Range	3.25–5
Length (mm)	
Mean	12.32
Median	11.5
Range	10–16

among implants placed in the posterior mandible is 10°.[15] In that respect, mandibular implants place in the 3rd molar region seem to have the greatest axial deviation even when guidance system are employed.[8]

In the present study, the mean angle of implant to opposite teeth was 167.88° ± 8.92°. When this data was further sorted between molars and nonmolar teeth, the interarch angular relationship for the molars (163.58°) was, in fact, within the normal ranges that were observed in the natural dentition (158°–164°).[16] To the contrary, this interarch relationship for the nonmolar teeth (170.42°) was somewhat shallower compared to these averages for the natural dentition (173°–176°). This phenomenon might be associated with pattern of ridge resorption that follows tooth extraction and inadvertently dictates implants position and angulation.

The use of panoramic radiographs in this study does contain some limitations. They have an inherited vertical distortion ranging from 20%–35%.[17] Also, due to its two dimensional nature, only mesiodistal measurements can be performed. Nonetheless, panoramic radiographs are the most commonly used imaging system in implant dentistry. In a study of 1527 consecutively treated implant patients, Vazquez and co-workers[18] concluded that this is a safe and cost/radiation efficient imaging modality in implant dentistry. More recently, Dudhia et al[19] compared the accuracy of angular measurements of teeth using panoramic radiographs versus

Table 2

Angular relationship between implants and adjacent/opposing structures

Measurements	Mean ± SD (°)	Range (°)
Angular relationship between the vertical axis of implant and adjacent teeth or implants	178.71 ± 9.18	129.7–206
Angular relationship between the vertical axis of implant and adjacent teeth	180.99 ± 11.21	129.7–206*
Angular relationship between the vertical axis of implant and adjacent implants	176.33 ± 5.54	159–193.1*
Angular relationship between the vertical axis of implant and opposing teeth	167.88 ± 8.92	137.7–179.8*

*$P = .0001$ (unpaired Student t test).

Table 3

The effect of positional guide on angular relationship

Measurements	With Guide mean ± SD (°)	Without Guide mean ± SD (°)	P-value*
Angular relationship between the vertical axis of implant and adjacent teeth or implants	178.22 ± 1.14	178.81 ± 0.71	.73
Angular relationship between the vertical axis of implant and adjacent teeth	179.86 ± 1.72	181.23 ± 1.24	.63
Angular relationship between the vertical axis of implant and adjacent implants	176.15 ± 1.26	176.36 ± 0.60	.89
Angular relationship between the vertical axis of implant and opposing teeth	164.46 ± 1.64	167.74 ± 0.79	.87

*P = unpaired Student t test.

Table 4

The association between implants location and its angular relationship with adjacent teeth

Site	Mean (°)	SE	*P*-value*
Incisors	180.55	1.10	.0001†
Premolars	181.62	0.79	
Molars	175.54	1.07	
Mandible	177.14	1.02	.0081
Maxilla	180.41	0.64	

*Analysis of variance with Scheffe's modification.
†Molars vs premolars and molars vs incisors.

CT scans. An overall 1.44° mean difference between the two imaging systems were reported.

In recent years, data are accumulating in support of the use of surgical guides[20] and three dimensional guidance systems.[21] In the present study, using a positional guide, there were no statistical differences in implant angulations (either to adjacent teeth or implants or to opposite teeth) between those performed with and without surgical guides. Mean interimplants angular relationship was almost identical (176.13° ± 1.26° and 176.36° ± 0.60°) with and without a guide, respectively. Recent years have brought a surge in the interest and research into the use of CT-based guidance systems in implant dentistry. Arsian and co-workers, using two commercially available 3D guidance systems, have reported very similar angular deviation between planned and actual implants axial position (mean values ranging between 2.9° ± 0.39° to 5.0° ± 1.66°).[9] Likewise, Talwar et al[10] reported inter-implants axial deviation of 3.27° ± 3.18° when a directional 3D guidance system was employed. Thus, it seems that an experienced surgeon may obtain good angular relationship of implants even without the use of surgical guides. These devices are therefore more appropriate when full-arch edentulous cases are treated to improve treatment outcome, or else for less experienced clinicians to shorten the learning curve.

Conclusion

Good axial angulation may be achieved in dental implants placed by an experienced clinician even when placed freehand. The mandibular posterior region is more prone to axial deviation and, as such, requires special attention.

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