The Relationship between Oral and Maxillofacial Surgeon Experience and Dental Implant Angulation Accuracy

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AIM: Dental implant placement requires precise angulation for long-term success and optimal restoration function. Therefore, this study explores the potential association between the experience of oral and maxillofacial surgeons and the accuracy of implant angulation, including its relationship to neighboring teeth and other implants.
METHODS: This retrospective study included 80 patients involving dental implants, each assessed through postoperative panoramic X-rays. Computer software was employed to measure the angle between the longitudinal axis of the selected implant and adjacent reference points. An angle less than 180° denoted convergence of the implant, while an angle greater than 180° indicated divergence.
RESULTS: The average angle regarding the implant-tooth relationship on the mesial side was 177.74 ± 6.94 (convergent), while on the distal side, it was 182.39 ± 7.77 (divergent). There were no statistically significant variations in insertion angles between procedures performed by experienced specialists (with over 5 years of expertise) and those performed by residents (with less than 5 years of experience). In comparing implants on the right side of the mouth to those on the left, given that all the surgeons were right-handed, no statistical significance was found for either the mesial reference (177.56 ± 7.44 vs. 178.06 ± 6.04, $p = 0.76$) or the distal reference (182.01 ± 8.38 vs. 183.15 ± 6.52, $p = 0.53$). However, a statistically significant difference was identified between the inclinations of implants towards the mesial reference compared to the distal inclinations in both cases ($p = 0.005$ for the right side and $p = 0.004$ for the left side).
CONCLUSIONS: In summary, satisfactory axial relationship in implant placement is effectively attained by both oral and maxillofacial surgery specialists and residents. Notably, implants consistently show a mesial inclination, irrespective of the specific side of the mouth. Additional research is needed to uncover the root cause of this inclination bias, aiming to promote the parallel alignment of implants with reference structures.

Keywords: implant angulation; surgeon experience; dental implants; implant placement accuracy; axial relationships; implant orientation; surgical experience

Background

Dental implants were initially adopted in the mid-1960s. However, technological advancements and widespread knowledge have transformed them into a highly sought-after alternative for replacing missing teeth [1]. A dental implant is inserted into the jawbone to support restorative components, such as crowns, bridges, or prostheses [2]. Numerous studies have substantiated that implants offer maximum efficiency and comfort, ensuring safety, aesthetic appeal, and high success rates [3,4,5]. Research suggests that dental implants may provide considerable stability than traditional dentures through osseointegration, where the implant fuses with the jawbone. This stability can result in several benefits, including reduced risk of slippage during chewing or speaking and potentially simpler oral hygiene practices than dentures [6]. The success of a dental implant depends on a combination of biological, medical, and mechanical factors. Success criteria, as formulated by Albrektsson *et al.* [7] and widely cited in numerous studies, include: no clinical mobility, absence of radiolucent evidence around the implant, maximum vertical bone loss of 0.2 mm one year after implant insertion, no persistent signs of pain, inflammation, or paresthesia, and avoiding damage to the mandibular canal. Success is defined as achieving these criteria in 85% of cases after 5 years or in 80% of cases after 10 years from the implant's insertion [7]. Ad-

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ditionally, the placement of the implant, including its location and angle, is crucial for aesthetic outcomes, periodontal health, and occlusal relationships [8]. Optimal positioning involves aligning the implant as parallel as possible to an adjacent tooth in the same arch [9]. Nevertheless, challenges related to implant positioning remain the most significant obstacle in the field of dental implants [2].

Studies suggest that the spatial orientation or axial relationship between dental implants and neighboring teeth, both adjacent and opposing, can influence overall bite function and the distribution of forces acting on the implants. Improper positioning of implants, sometimes called "suboptimal", may lead to bone loss around the implant, difficulties achieving osseointegration, and an increased risk of mechanical failure [9,10].

Furthermore, recent research has indicated a direct correlation between the experience level of the attending physician and the success of dental implants, defined by the implant's survival in the patient's mouth for over a year from the date of implantation [11]. In cases where the implant served as an abutment for a prosthesis, success has been assessed by the extent of repairs required for the prosthesis [12]. When comparing different training programs such as periodontics, prosthodontics, and oral and maxillofacial surgery, residents in the periodontics have demonstrated higher percentages of implant survival after one year. Furthermore, implant survival rates increased with the years of seniority among residents, indicating that greater experience results in higher implant survival rates [11].

Previous studies examining implant angles, reported that using a guiding stent did not significantly enhance implant placement compared to the manual skills of the attending physician [9,13,14]. Notably, most studies on implant angles were conducted on models of phantom jaws, which allow for a meticulous examination but fail to account for real-time factors present in patients' jaws, such as limitations in mouth opening and saliva secretion [9,13,15,16].

This study investigates potential differences in the angle of dental implant insertion among residents and specialists in oral and maxillofacial surgery at various stages of their training. The comparison within an oral and maxillofacial surgery residency setting has not been explored previously, and the findings could have implications for the residency curriculum.

Materials and Methods

Study Participants

This retrospective study analyzed the clinical records of patients who underwent dental implants at the Department of Oral and Maxillofacial Surgery at the Baruch Padeh Tzafon Medical Center from 2017 to 2019. The research received approval from the institutional review board (IRB) of the Baruch Padeh Tzafon Medical Center (approval number: 0038-20-POR, date of approval: April 21, 2020) and adhered to the principles outlined in the Declaration of Helsinki. Being a retrospective study analyzing patient files, the study was exempted from obtaining informed consent.

All implants were inserted following a standardized surgical protocol. Initially, local anesthesia was administered followed by the elevation of buccal and lingual flaps. This was succeeded by pilot drilling and subsequent drilling to achieve the predetermined length and diameter. Each surgical procedure was performed by a sole surgeon, and residents conducted their procedures under the supervision of a senior surgeon. It is crucial to note that seniors could advise the residents during surgery but they could not physically intervene.

To detect a 2° difference between two groups (specialists and residents) with a standard deviation of 10°, a total of 80 cases (40 in each group) were needed. The study aimed for a significance level of 5% and a power of 80%.

The inclusion criteria for study participants were set as follows:

- All cases involved dental implant procedures with a corresponding postoperative panoramic radiograph.
- In instances where multiple implants were placed, the mesial implant was selected for consistency.
- Cases with minor augmentation using the guided bone regeneration (GBR) method along with initial implant stability.

However, the cases were excluded from this analysis using the criteria described below:

- Cases lacking an adjacent tooth or implant near the tested implant for angle comparison.
- Cases with intentionally angled implants to avoid bone augmentation or prevent injury to adjacent anatomical structures, as documented in the patient's file before the procedure.
- Cases with misaligned reference teeth or implants.
- Cases involving bone block augmentation or where augmentation was performed separately from the implantation (pre-implantation with subsequent healing time).

The following general data were collected:

Case data: patient's age, implantation date, jaw (maxilla/mandible), side (left/right), the implanted tooth (1–7), immediate implant status (yes/no), immediate loading status (yes/no), augmentation type at implantation (none, closed sinus, open sinus, GBR), implant length, implant diameter, adjacent mesial structure (tooth, implant, missing), adjacent distal structure (tooth, implant, missing), implant parallelism angle to adjacent mesial structure (in degrees), implant parallelism angle to adjacent distal structure (in degrees).

Surgeon data: experience level as a specialist or resident in oral and maxillofacial surgery (specialist if more than 5 years of experience, resident if less than or equal to 5 years of experience), sex (male/female), and dominant hand (right/left).

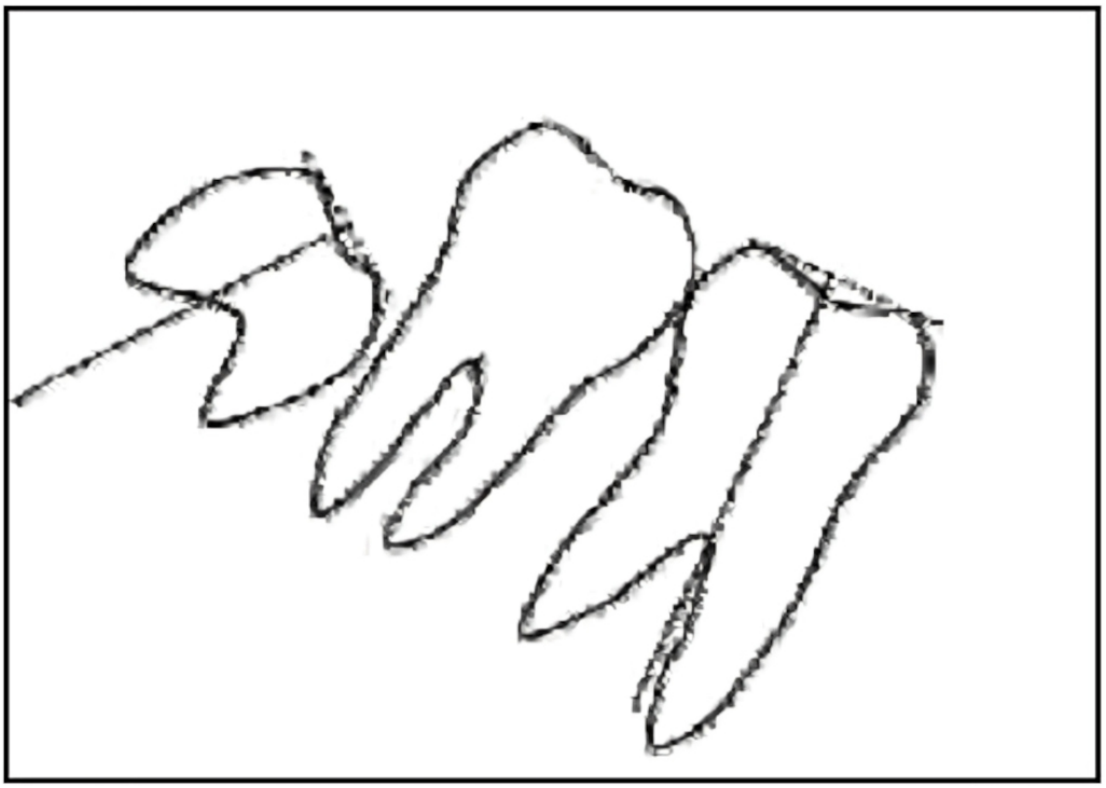

Fig. 1. Determination of the longitudinal axis of the molars. Taken from Tarazona *et al*. 2010 with permission Ref. [17].

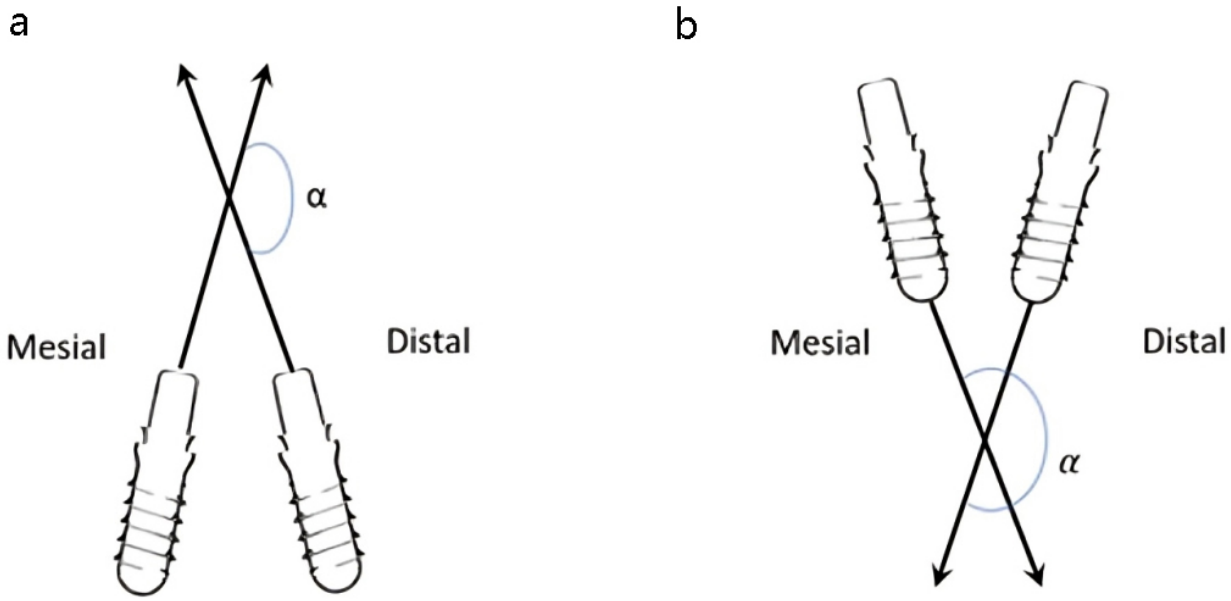

Fig. 2. The parallelism of the implant or tooth longitudinal axes. (a) Convergence of the longitudinal axes of the implants results in an angle $\alpha > 180$ degrees. (b) Longitudinal axial separation of the implants results in an angle $\alpha < 180$ degrees. (Created on Vectr Software (https://vectr.com/), Pixlr Pte. Ltd., Singapore).

Assessing Implant Alignment

We evaluated the parallelism (straightness) of dental implants placed by resident and specialist surgeons. Angles were measured using a software program (RadiAnt DICOM Viewer 2021.1, Medixant, Poznań, Poland) within the Picture Archiving and Communication System (PACS). PACS is a digital system that stores and displays medical images, such as X-rays and computed tomography (CT) scans.

Table 1. Baseline characteristics of patient and implant.

	Total	Residents	Specialists	*p*-value
Count	80	40	40	
Female	59	29	30	0.8 ($\chi^2 = 0.065$)
Male	21	11	10	
Mean age (years)	55.1 ± 16.8	53.07 ± 19.45	57.15 ± 13.58	0.28 ($t = 1.088$)
Age range	19–82	19–82	19–77	
Maxilla	40	20	20	1 ($\chi^2 = 0$)
Mandible	40	20	20	
Location				
Canines and incisors	22	13	9	
Premolars	44	21	23	0.58 ($\chi^2 = 1.104$)
Molars	14	6	8	
Diameter (mm)				
Mean	3.68 ± 0.46	3.58 ± 0.29	3.78 ± 0.56	
Median	3.7	3.7	3.75	0.048 ($t = 2.006$)
Range	3.3–5	3.3–4.2	3.3–5	
Length (mm)				
Mean	12.16 ± 1.75	12.32 ± 1.47	11.98 ± 1.99	
Median	13	13	13	0.39 ($t = 0.869$)
Range	6–16	8–16	6–16	
Other procedure				
None	28	18	10	
Open sinus lift	8	3	5	0.16 ($\chi^2 = 5.136$)
Closed sinus lift	6	4	2	
GBR	38	15	23	

GBR, guided bone regeneration.

Table 2. The distribution of correlation factors for the measured implants.

	Total		Residents		Specialists		*p*-value (χ^2)
	Implant	Tooth	Implant	Tooth	Implant	Tooth	
Mesial reference (80 implants)	18	62	9	31	9	31	1 (0)
Distal reference (76 implants)	64	12	32	7	32	5	0.6 (0.281)
p-value (χ^2)	<0.0001 (59.52)		<0.0001 (28.052)		<0.0001 (31.611)		

Measurement Technique

The software within PACS creates a digital representation of the implant and surrounding teeth. It measures the angle between the long axis of the implant (an imaginary line running tip to base) and the long axis of the adjacent tooth or implant (on both sides and in front if present). This angle shows how parallel the implant is to the adjacent teeth. The longitudinal axis of the molar is perpendicular to the line that joins one of the mesial and distal cuspids of the molar, as depicted in Fig. 1 (Ref. [17]).

Convergent Angle: If the implant angulated inwards towards the adjacent tooth or implant, the angle measurement was recorded as less than 180 degrees, imagining two lines leaning inwards like a chevron pointing downwards (<).

Divergent Angle: Conversely, if the implant angulated outwards, away from the adjacent tooth or implant, the angle was recorded as greater than 180 degrees, imagining two lines leaning outwards like a chevron pointing upwards (>). A visual representation of this angulation assessment is shown in Fig. 2.

Statistical Analysis

The data were analyzed using Prism 10.1.2 Software by GraphPad Inc. (La Jolla, CA, USA) in two steps. First, descriptive statistics were utilized to summarize the data for each group (residents and specialists) using measures like mean angle and range of angles. Second, a comparative analysis of implant angulation between the resident and specialist groups was performed using an independent-sample *t*-test. Additionally, a chi-square test was performed to investigate if any factors influenced the distribution of implants among patients. This test helps identify if factors like jaw location (upper vs. lower jaw) played a role in surgeon's (resident or specialist) ability to place the implant.

Results

We examined 80 implants involving 80 patients (21 men and 59 women). The participants were evenly distributed between the two groups based on their experience level: the resident group (up to 5 years of experience) and the special-

Table 3. The angles between the implants and adjacent reference factors—implants or teeth.

	Total		Residents		Specialists		*p*-value (*t*-test)
	Mean and SD in degrees	Range	Mean and SD in degrees	Range	Mean and SD in degrees	Range	
The angle between the implant and the mesially adjacent implant/tooth (80 implants)	177.74 ± 6.94	164.4–201.5	176.6 ± 7.72	164.4–201.5	178.88 ± 5.96	164.6–200.3	0.14 (1.478)
The angle between the implant and the distally adjacent implant/tooth (76 implants)	182.39 ± 7.77	156.2–199.5	182.61 ± 8.46	169.4–199.5	182.18 ± 7.12	156.2–195	0.82 (0.239)
p-value (*t*-test)	0.0001 (3.946)		0.0015 (3.297)		0.0021 (3.13)		

Table 4. The angles between the implants and adjacent reference factors—implants or teeth—relative to the side of the mouth where they were placed.

	Right side (52 implants)		Left side (28 implants)		*p*-value (*t*-test)
	Mean and SD in degrees	Range	Mean and SD in degrees	Range	
The angle between the implant and the mesially adjacent implant/tooth	177.56 ± 7.44	164.4–201.5	178.06 ± 6.04	166.1–195.9	0.76 (0.305)
The angle between the implant and the distally adjacent implant/tooth	182.01 ± 8.38	156.2–199.5	183.15 ± 6.52	171.4–195	0.53 (0.625)
p-value (*t*-test)	0.005 (2.863)		0.004 (3.03)		

ist group (over 5 years of experience). All implant procedures were conducted by right-handed practitioners, with the majority being male therapists (97.5%).

Patient and implant details are presented in Table 1. The average age of patients was 55.1 ± 16.8 (range 19–82). Implants were evenly distributed between upper and lower jaws, predominantly in the posterior regions (14 molars, 44 premolars, 22 incisors and canines). Most implants were of standard diameter, ranging from 6 to 16 mm in length (median length 13 mm, median diameter 3.7 mm). Furthermore, eight implants were placed with open sinus lifting, six with closed sinus lifting, and 38 with bone grafting, such as guided bone regeneration (GBR).

When comparing the specialist group (over 5 years of experience) with the resident group, there was no significant difference in the gender distribution between the patient groups ($p = 0.8$). Furthermore, there were no statistically significant differences between the groups regarding the distribution of implants between the jaws ($p = 1$) or their location in the mouth ($p = 0.58$).

Additionally, on average, specialists implanted significantly larger-diameter implants compared to the residents (3.78 ± 0.56 vs. 3.58 ± 0.29, $p = 0.048$). However, there was no significant difference between the groups in the length of the implants ($p = 0.39$). When comparing additional procedures performed during implantation, specialists conducted non-significantly open sinus lifts (20% vs. 7.5%, $p = 0.16$), conducted fewer closed sinus lifts (10% vs. 15%), and fewer implants without additional procedures (45% vs. 25%).

During the examination of implants, if more than one implant was presented in a quarter of the mouth, the most mesial implant was selected for measurement in relation to the adjacent mesial tooth/implant and the distal implant/tooth presented or performed in the same operation. Out of the total implants, 76 had a distal tooth or implant associated with them, as shown in Table 2.

In terms of reference factors, a significant difference ($p < 0.0001$) was observed between the mesial reference factor (tooth in 77.5% of cases) and the distal reference factor (implant in 84.2% of cases). This significant difference ($p < 0.0001$) between mesial and distal reference factors was consistent in both the specialist and resident groups (77.5% for the tooth on the mesial side in both groups, 82.1% and 86.5% for the implant on the distal side in the specialist and resident groups, respectively). There was no significant difference between the specialist and resident groups regarding reference factors in either direction ($p = 1$ for mesial, $p = 0.6$ for distal).

The angular relationship between implants and adjacent teeth is detailed in Table 3. The average angle concerning the implant or tooth was 177.74 ± 6.94 on the mesial side

Table 5. The angles between the implants and adjacent reference factors—implants or teeth—compared to the side of the mouth where they were performed concerning the molars and premolars only (58 implants).

	Total (58 implants)		Right side (36 implants)		Left side (22 implants)		*p*-value (*t*-test)
	Mean and SD in degrees	Range	Mean and SD in degrees	Range	Mean and SD in degrees	Range	
The angle between the implant and the mesially adjacent implant/tooth	177.13 ± 6.41	164.4–200.3	176.86 ± 7.21	164.4–200.3	177.84 ± 4.89	167–189.2	0.58 (0.562)
The angle between the implant and the distally adjacent implant/tooth	184.1 ± 6.98	170.7–199.5	184.83 ± 7.02	170.7–199.5	182.85 ± 6.92	171.4–195	0.3 (1.048)
p-value (*t*-test)	0.0001 (5.601)		0.0001 (4.752)		0.008 (2.773)		

and 182.39 ± 7.77 on the distal side. Assessment of the angle range indicated a deviation of up to 20 degrees in all cases, without exceeding this range (164–201 degrees for the mesial side, 156–199 degrees for the distal side). A statistically significant difference ($p = 0.0001$) was found between the mesial and distal angles, indicating a slight tendency for convergence on the mesial side compared to a slight divergence on the distal side. Furthermore, no statistically significant difference in implant angles was observed between specialists and residents ($p = 0.14$ on the mesial side, $p = 0.82$ on the distal side). Regarding the angle differences between the mesial and distal reference factors, a significant difference was found between the sides in both the specialist ($p = 0.0021$) and resident ($p = 0.0015$) groups.

In the comparison between implants performed on the right side of the mouth (52 implants) and those on the left side (28 implants), as presented in Table 4, no statistically significant difference was observed between the groups, both in the measurement relative to the mesial reference (177.56 ± 7.44 vs. 178.06 ± 6.04, $p = 0.76$) or relative to the distal reference (182.01 ± 8.38 vs. 183.15 ± 6.52, $p = 0.53$). Consistent with previous findings, a significant difference was found between the inclination of the implants towards the mesial reference and their inclination towards the distal reference ($p = 0.005$ on the right, $p = 0.004$ on the left).

The trend persisted when examining relationships within the jaws alone (58 implants), particularly in the posterior region. There was no statistical difference between posterior implants on the right side (36 implants) compared to those on the left regarding both mesial and distal reference ($p = 0.58$ and $p = 0.3$, respectively, Table 5).

Discussion

This study explored the link between implant angulation (angle of insertion) and the surgeon's experience level in dental implant surgery. Precise implant placement is crucial for both esthetic and functional reasons, influencing bone and soft tissue preservation and the implant's ability to withstand biting forces [18,19,20]. The analysis revealed no significant correlation between the experience of a maxillofacial surgeon and the angulation of the implant relative to either the mesial (front) or distal (back) reference points, regardless of whether the reference was a tooth or another implant (Table 3). This finding contrasts with previous studies that reported a learning curve for implant placement, where angulation improved with experience [12,18,21]. A study by Machtei *et al*. [9] on implant angulation suggests that skilled surgeons aim for parallelism with the reference point (tooth or implant), irrespective of using a guiding template or freehand placement.

Several possible explanations exist for the difference between our findings and previous research. First, oral and maxillofacial surgeons receive training that emphasizes manual skills crucial for proper implant insertion techniques. While their implant experience might be limited, their overall clinical exposure equips them with the necessary skills for accurate implant placement. Additionally, residents often perform implant surgeries under the close supervision of experienced surgeons and in controlled environments with less time pressure.

Interestingly, our study observed a consistent pattern in implant angulation regardless of surgeon's experience. Implants tended to converge (angle less than 180°) towards the mesial reference point and diverge (angle greater than 180°) from the distal reference point (Table 3). This finding aligns with previous studies on freehand implant placement, which reported a bias towards a mesial tilt, especially in the absence of distal teeth [22,23].

Several hypotheses attempt to explain this bias: Limited Working Space: The natural limitations of the mouth opening and instrument access might restrict angulation during implant insertion [22,23]. Central Fixation Bias: This psychological principle suggests that humans focus more on the center of their visual field than the periphery. Applied to implant placement, this could mean that surgeons subconsciously favor the mesial reference point, leading to a mesial angulation bias.

We also observed a significantly higher prevalence of teeth on the mesial side of implants than the distal side (Table 2). This finding aligns with the fact that back teeth, particularly

molars, are more prone to loss than front teeth [24,25]. An intriguing avenue for future research is to explore a potential causal link between the observed converging angulation with a mesial tooth and the diverging angulation with a distal implant.

Furthermore, our study reassuringly demonstrated no significant difference in implant angulation (mesiodistal dimension) between the right and left sides of the patient's mouth, despite all surgeons being right-handed (Table 4). This trend persisted even when analyzing posterior teeth (premolars and molars), where access is more challenging (Table 5). Other studies have reported comparable results, suggesting that handedness does not significantly impact implant angulation [22,26].

Additionally, this study indicated that experienced surgeons often undertake more complex implant procedures, such as sinus lifts or GBR, alongside simpler implant placements. Established research across various surgical disciplines consistently shows that experience and seniority contribute to improved safety and efficiency in performing complex procedures with fewer complications [23,24,25]. Conversely, younger clinicians might tend to adopt more conservative treatment approaches, as is generally expected.

Furthermore, this study provides valuable insights into the relationship between surgeon experience and implant angulation. While the findings suggest no direct link between experience and angulation, they highlight interesting patterns in implant angulation bias and the potential influence of tooth distribution. Future research exploring the causal relationship between angulation and tooth position could be valuable.

However, despite some promising observations, our study has some limitations that must be addressed. Panoramic radiographs are a mainstay in dentistry, particularly for initial assessments in dental implant procedures. They are widely adopted due to two key advantages: (1) Cost-Effectiveness: Compared to more sophisticated imaging techniques like cone-beam computed tomography (CT) scans, panoramic X-rays are more affordable. This translates to a more accessible diagnostic tool for patients and dental professionals. (2) Safety: Panoramic X-rays deliver a lower radiation dose than CT scans. This is especially important for patients who may be more sensitive to radiation exposure or require frequent monitoring [24]. However, it is crucial to acknowledge the limitations of panoramic X-rays. Unlike CT scans that provide a three-dimensional (3D) view, panoramic radiographs offer a two-dimensional (2D) image. This restricts the information they can reveal about implant placement. While they can show implant position in the front-to-back plane (mesiodistal), they lack detail regarding depth and angulation in the jawbone. Secondly, panoramic images are prone to distortion, particularly in the horizontal plane. This distortion is most pronounced near the center of the image, often affecting the perception of the size and position of the front teeth [27].

Conclusions

The study reveals that satisfactory axial relationship in implant placement can be achieved by both oral and maxillofacial surgery specialists and doctors in the stages of specialization. While there is a tendency for implants to be inserted with a mesial tilt, no significant difference was observed between implants placed on the right or left side of the mouth. These findings suggest a need for further research to understand and address the bias, aiming to achieve parallel implant placement into adjacent structures.

Availability of Data and Materials

The data that support the findings of this study are available from the corresponding author upon reasonable request.

Author Contributions

The authors confirm contribution to the paper as follows: study conception and design: IAE, AL; data acquisition: HS; analysis and interpretation of results: SA, MVJ; draft manuscript: MVJ, AL. All authors revised the manuscript critically for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

The research received approval from the institutional review board (IRB) of the Baruch Padeh Tzafon Medical Center (approval number: 0038-20-POR, date of approval: April 21, 2020) and adhered to the principles outlined in the Declaration of Helsinki. The study was granted exemption from obtaining informed consent by the IRB of the Baruch Padeh Tzafon Medical Center due to its retrospective nature.

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Conflict of Interest

The authors declare no conflict of interest.

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