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Mouth opening limitation and influence of age and surgical location for static fully guided dental implant placement: an observational, cross-sectional clinical study

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Abstract. The influence of age and region of the mouth was assessed in regard to mouth opening in fully guided implant placement. Ninety patients were included in this study, 30 in each of three age groups (20–34, 35–55, and > 55 years). Maximum passive mouth opening was recorded in three locations: incisal, canine, and molar. The minimum distance required to allow the bone drilling sequence through a static fully guided approach was analysed for four implant systems: Straumann, MIS Dentsply, Astra Tech Dentsply, and Dentium. The mean $\pm$ standard deviation maximum mouth opening (all 90 patients) was 46.34 ± 7.70 mm, 36.82 ± 5.92 mm, and 30.99 ± 5.40 mm in the incisal, premolar, and molar region, respectively. No significant difference in mouth opening at any of the three locations was found between the age groups (all $P > 0.05$). However, a correlation was found between increasing age and decreasing average mouth opening in all three mouth regions; each additional 1 year resulted in a mean reduction of 0.13 mm, 0.09 mm, and 0.08 mm in the incisal, premolar, and molar region, respectively. The minimum required mouth opening was most likely to be met for implant placement in the incisal region (98.9% of all patients) and least likely to be met for placement in the molar region, particularly for older patients (as low as 30% of patients). Mouth opening remains a major limitation in fully guided implant surgery, especially in posterior areas and in older patients. The use of some implant systems in the posterior area may be limited to only one in three patients.

Keywords: Computer-aided surgery; Mouth rehabilitation; Passive range of motion; Age groups; Tooth loss; Dental implants.

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Dental implantology is constantly evolving and improving. Better materials and macro- and micro-designs and surfaces are being developed in pursuit of faster and more predictable osseointegration, with continuous improvements in the long-term prognosis.¹ Moreover, from the prosthetic point of view, implant connections and intermediate phases have evolved to maintain the peri-implant environment, with increased focus on preventing peri-implant bone loss, reducing the risk of peri-implantitis, making attachments more hygienic, and considering biological spaces.^{2,3}

However, despite the evolution in technology, the experience, skills, and knowledge of the surgeon remain independent risk factors and thus may represent a critical factor influencing the achievement of a good long-term prognosis.⁴ Digital planning provides a better preoperative picture by combining three-dimensional (3D) cone beam computed tomography, stereolithography, and intraoral scan data. Thus, improvements in digital implantology can decrease the human error factor when applying the pre-surgical plan to the patient and enhance the accuracy of implant positioning, thereby improving the treatment performance and long-term predictability.⁵⁻⁷ Overall, the static fully guided approach to implant placement has demonstrated the highest accuracy between the pre-surgical plan and final implant placement, followed by the half-guided approach (guided drilling), and consequently the use of surgical splints to insert dental implants is increasingly widespread.⁸⁻¹⁰

Although many studies have focused on digital implantology with the aim of identifying better drilling sequences and improved surgical splint designs while addressing various clinical situations, mouth opening continues to be a major limitation of static-guided surgery.¹¹ The current study is therefore novel in specifying the minimum mouth opening required for four different implant systems.

The aim of this study was to determine the influence of age and surgical location on the suitability of patients for fully guided implant placement surgery according to four different implant systems.

Materials and methods

This observational, cross-sectional clinical study was performed in the Oral and Maxillofacial Surgery Dental

Clinic at the International University of Catalonia (Barcelona, Spain) and was approved by the Ethics Committee for Research of the International University of Catalonia (CIR-ECL-2019-07). The STROBE guidelines were followed in the reporting of this study (<https://www.equator-network.org/reporting-guidelines/strobe/>).

Thirty consecutive patients in each of three age groups were recruited, for a total of 90 patients: group 1 (G1) included patients aged 20–34 years, group 2 (G2) included patients aged 35–55 years, and group 3 (G3) included patients older than 55 years.

The following inclusion criteria were applied: healthy participants (American Society of Anesthesiologists (ASA) class I and II); able to follow instructions; attended the Oral and Maxillofacial Surgery Dental Clinic at the International University of Catalonia for the replacement of a missing tooth or teeth with dental implants, in either jaw (maxilla or mandible). The exclusion criteria were as follows: history of a temporomandibular joint disorder (including trismus), total edentulism, or partial edentulism affecting the opposite tooth at any of the study measurement sites. Patients who met the eligibility criteria were enrolled in the study and signed an informed consent form before any procedures were performed.

For each patient, maximum passive mouth opening measurements were obtained using a metal caliper in three different oral locations: (1) incisal (between the edge of the upper central incisor and the incisal area of the opposite incisor); (2) premolar (between the buccal cusp of the upper first premolar and the occlusal area of the opposite tooth); (3) molar (between the mesiobuccal cusp of the first molar and the occlusal area of the antagonist molar) (Fig. 1).

For the assessment of the minimum distance required to allow the bone drilling sequence before dental implant placement using a fully guided approach, the following two distances were measured: the distance from the most coronal area of the contra-angle head (NSK X-SG20L; NSK, Tokyo, Japan) to the end of the shortest guided bur positioned inside the contra-angle head, and the height of the shortest sleeve required. These two distances were measured and summed for each of four implant systems that use fully guided implant surgical tools (Fig. 2). The shortest bur of each implant

system for a minimum implant length of 6 mm was considered in the measurement. The four dental implant systems from four companies that were analysed in this study were Straumann (Institut Straumann AG, Basel, Switzerland), MIS Dentsply (MIS Implant Technologies, Misgav, Israel), Astra Tech Dentsply (Dentsply Sirona, Charlotte, NC, USA), and Dentium (Dentium USA, Cypress, CA, USA).

Considering that the patient measurements must correspond to the edentulous spaces to facilitate implant placement, the mean height of the crown of each selected tooth was subtracted from the final total height in the dentulous spaces to obtain reliable measurements in the dentate situation.^{12,13} These values were a mean 11.3 mm, 9.3 mm, and 8 mm for the maxillary incisal, premolar, and molar positions, respectively, and 10 mm, 9.3 mm, and 8.2 mm for the mandibular incisal, premolar, and molar positions, respectively.

Statistical analysis

Descriptive statistics were computed: maximum mouth opening values were analysed at the three different measurement sites (incisal, premolar, and molar regions), and the mean, standard deviation, minimum and maximum, median, and 25th (Q1) and 75th (Q3) percentile values were calculated for each age group. In addition, an analysis of absolute and relative frequencies was performed. The inferential analysis involved an analysis of variance test (ANOVA) to evaluate the mean maximum mouth opening values in the three age groups; the Bonferroni correction was also applied. The Pearson correlation coefficient (r) and simple linear regression models were used to assess the linear relationship between maximum mouth opening and patient age for each of the three mouth regions. Finally, a binary logistic regression model was established to determine the odds ratio (OR) and 95% confidence interval (CI) for the utility of each implant system in relation to the tooth location, independent of age. Statistical significance was set at $P = 0.05$ in all of the analyses.

Results

Thirty consecutive patients in each of three age groups (20–34, 35–55, and

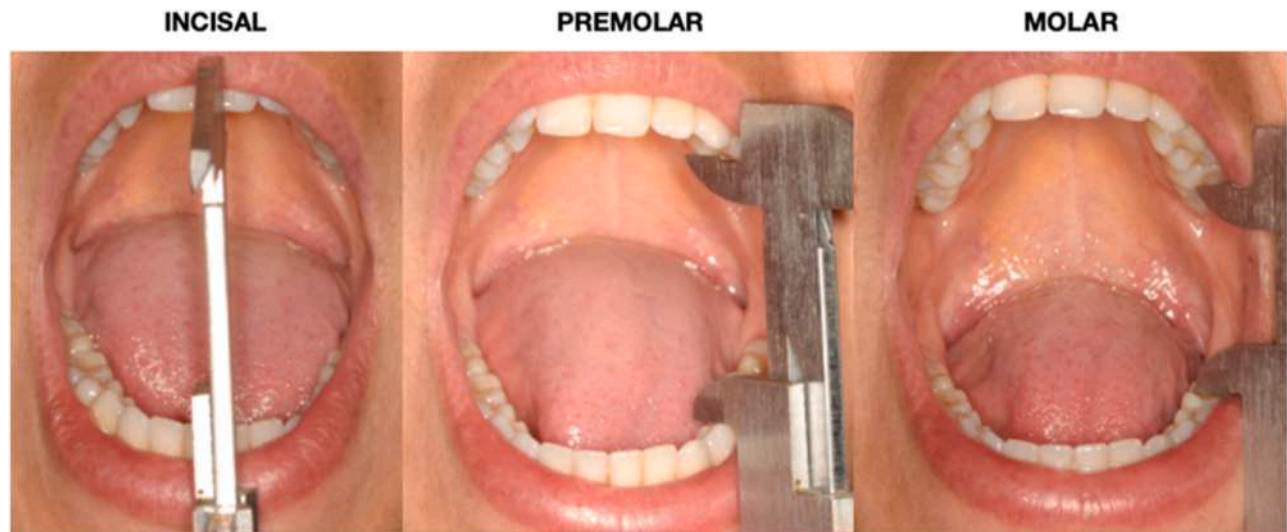


Fig. 1. Locations for the measurement of maximum mouth opening: (A) incisal, (B) premolar, and (C) molar regions.



Fig. 2. The minimum distance required was defined as the sum of distances 'A' and 'B', where 'A' is the distance from the most coronal area of the contra-angle head to the end of the shortest guided burr positioned inside the contra-angle head and 'B' is the sleeve height.

> 55 years) were recruited, for a total of 90 patients. The mean $\pm$ standard deviation age was 45.6 ± 16.9 years for all patients, and 25.3 ± 2.4 years in G1, 46.8 ± 5.4 years in G2, and 64.6 ± 6.6 years in G3.

Maximum mouth opening

The mean maximum mouth opening distance for all patients (global) was 46.34 ± 7.70 mm in the incisal area, 36.82 ± 5.92 mm in the premolar area, and 30.98 ± 5.40 mm in the molar area, while the global median values were 45 mm, 36 mm, and 31 mm, respectively.

In all three age groups, mean maximum opening was greatest in the incisal area: 48.73 ± 8.69 mm in G1, 46.00 ± 6.81 mm in G2, and 44.30 ± 7.04 mm in G3. In contrast, the molar area had less inter-occlusal space, with an average of 32.33 ± 5.84 mm in G1, 30.77 ± 5.09 mm in G2, and 29.83 ± 5.13 mm in G3. The descriptive data including the mean, median, maximum and minimum, and 25th and 75th percentile values for the total sample and by age group are presented in full in Table 1.

No significant difference in mouth opening between the age groups was found in any of the three mouth regions

($P = 0.078$, $P = 0.136$, and $P = 0.195$ for the incisal, premolar, and molar region, respectively). However, a trend towards significance was observed for the difference in mean maximum mouth opening in the incisal location between the youngest and oldest age groups ($P = 0.077$), indicating that as age increases, the maximum oral opening decreases. No similar trend was observed for any of the other inter-group comparisons for any of the three oral locations. Pearson correlation analysis of maximum mouth opening according to location and patient age demonstrated that increasing age was associated with decreasing average mouth opening (incisal region, $r = -0.28$; premolar region, $r = -0.25$; molar region, $r = -0.24$). Each additional 1-year of age resulted in a mean reduction of 0.13 mm, 0.09 mm, and 0.08 mm in the incisal, premolar, and molar region, respectively. Fig. 3 illustrates the variation in maximum mouth opening by age group and mouth region.

Minimum distance required

The minimum distance required for bone drilling through a fully guided approach was calculated to be 36 mm for MIS Dentsply, 38 mm for Dentium, 39.5 mm for Straumann, and 41 mm for Astra Tech Dentsply. Considering these data, Table 2 details the percentages of the study patients fulfilling the fitting requirements for fully guided surgery (with 95% CI) according to the four implant systems, by age group and oral location. All implant systems except for the Straumann implant system showed

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Table 1. Maximum mouth opening values by age group and mouth position, in millimetres. Results of one-way ANOVA *F*-test and Bonferroni pairwise multiple comparisons.

	Study group				Comparison between groups			
	Total	G1 (20–34 years)	G2 (35–55 years)	G3 (> 55 years)	Overall	G1 vs G2	G1 vs G3	G2 vs G3
Incisal area								
Number	90	30	30	30				
Mean	46.34	48.73	46.00	44.30	<i>F</i> = 2.63	<i>P</i> = 0.495	<i>P</i> = 0.077	<i>P</i> = 1.000
SD	7.70	8.69	6.81	7.04	<i>P</i> = 0.078			
Min	24.00	32.00	31.00	24.00				
Max	68.00	68.00	64.00	62.00				
Q1	41.00	42.00	41.00	41.00				
Median	45.00	49.50	46.00	44.00				
Q3	52.00	55.00	50.00	47.00				
Premolar area								
Number	90	30	30	30				
Mean	36.82	38.53	36.33	35.60	<i>F</i> = 2.04	<i>P</i> = 0.447	<i>P</i> = 0.166	<i>P</i> = 1.000
SD	5.92	6.09	5.96	5.49	<i>P</i> = 0.136			
Min	20.00	25.00	24.00	20.00				
Max	52.00	51.00	52.00	46.00				
Q1	33.00	35.00	33.00	32.00				
Median	36.00	40.00	36.00	36.00				
Q3	41.00	42.00	39.00	39.00				
Molar area								
Number	90	30	30	30				
Mean	30.98	32.33	30.77	29.83	<i>F</i> = 1.66	<i>P</i> = 0.784	<i>P</i> = 0.224	<i>P</i> = 1.000
SD	5.40	5.84	5.09	5.13	<i>P</i> = 0.195			
Min	17.00	22.00	20.00	17.00				
Max	45.00	44.00	45.00	40.00				
Q1	28.00	29.00	28.00	27.00				
Median	31.00	32.00	31.00	29.50				
Q3	34.00	37.00	33.00	33.00				

Max, maximum; Min, minimum; Q1, 25th percentile; Q3, 75th percentile; SD, standard deviation.

no difference between the maxillary and mandibular locations.

Mouth opening fitting requirements

A higher percentage of the 90 study patients were deemed suitable for fully guided surgery in the incisal region (98.9% for all implant systems) when compared to the premolar and molar regions (81.1–96.7% and 34.4–76.7%,

respectively, depending on the implant system). In contrast, fewer patients were deemed suitable for fully guided surgery in the molar region (76.7%, 58.9%, 45.6%, and 34.4% of all patients, with MIS Dentsply, Dentium, Straumann, and Astra Tech Dentsply, respectively).

When analysing the probability of fitting for each implant system in each location in relation to patient age, MIS

Dentsply and Astra Tech Dentsply implant fitting was independent of age in all three areas of the mouth: for MIS Dentsply, OR 0.87 (95% CI 0.71–1.06; *P* = 0.153), OR 0.99 (95% CI 0.93–1.06; *P* = 0.776), and OR 0.99 (95% CI 0.96–1.02; *P* = 0.414) for the incisal, premolar, and molar areas, respectively; for Astra Tech Dentsply, OR 0.87 (95% CI 0.71–1.06; *P* = 0.153), OR 0.99 (95% CI 0.96–1.02; *P* = 0.485), and OR 0.98 (95% CI 0.95–1.01; *P* = 0.113) for incisal, premolar, and molar areas, respectively (Table 2).

Similarly, the probability of fitting a Dentium implant in any of the three areas was independent of patient age, although a certain trend was detected in the molar area (OR 0.98, 95% CI 0.95–1.00; *P* = 0.075), in that each additional year of age reduced the probability of fitting by 2%. In the incisal area (OR 0.87, 95% CI 0.71–1.06; *P* = 0.153) and premolar area (OR 0.98, 95% CI 0.92–1.04; *P* = 0.479), no association was detected (Table 2).

Finally, the probability of fitting a Straumann implant in the incisor or premolar area was also independent of patient age. However, a significant impact of age was detected for the molar area, in that each additional year of age

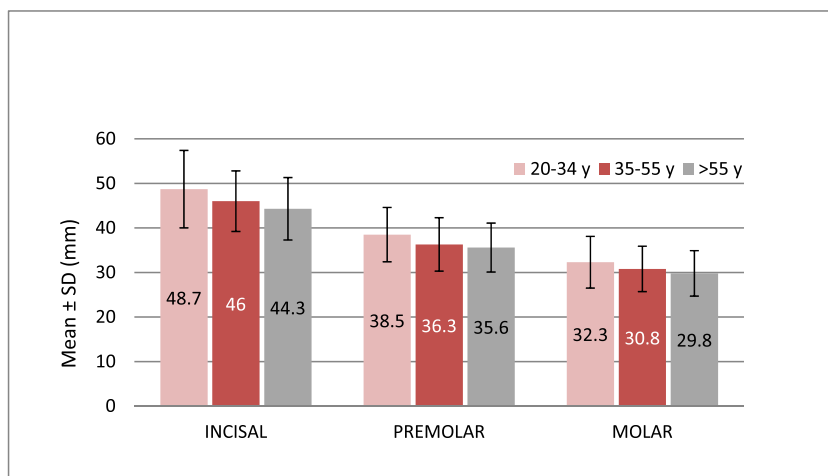


Fig. 3. Maximum mouth opening by age group and mouth region; mean ± standard deviation values.

Table 2. Frequency of patients fulfilling the fitting requirements for fully guided surgery based on the four different implant systems: MIS Dentsply, Dentium, Straumann (specified separately for the maxilla and mandible), and Astra Tech Dentsply, by age group and mouth position.

	MIS Dentsply		Dentium		Straumann, maxilla		Straumann, mandible		Astra Tech Dentsply	
	<i>n</i> (%) ^a	CI	<i>n</i> (%) ^a	CI	<i>n</i> (%) ^a	CI	<i>n</i> (%) ^a	CI	<i>n</i> (%) ^a	CI
Global										
Incisal	89 (98.9)	93.9–99.9	89 (98.9)	93.9–99.9	89 (98.9)	93.9–99.9	89 (98.9)	93.9–99.9	89 (98.9)	93.9–99.9
Premolar	87 (96.7)	90.6–99.3	86 (95.6)	89.0–98.8	79 (87.8)	81.0–94.5	82 (91.1)	85.2–97.0	73 (81.1)	73.0–89.2
Molar	69 (76.7)	67.9–85.4	53 (58.9)	48.7–69.1	41 (45.6)	35.3–55.8	41 (45.6)	35.3–55.8	31 (34.4)	24.6–44.3
20–34 years										
Incisal	30 (100)	88.4–100	30 (100)	88.4–100	30 (100)	88.4–100	30 (100)	88.4–100	30 (100)	88.4–100
Premolar	29 (96.7)	82.8–99.9	29 (96.7)	82.8–99.9	27 (90.0)	73.5–97.9	27 (90.0)	73.5–97.9	25 (83.3)	65.3–94.4
Molar	24 (80.0)	61.4–92.3	21 (70.0)	50.6–85.3	17 (56.7)	37.4–74.5	17 (56.7)	37.4–74.5	13 (43.3)	25.5–62.6
35–55 years										
Incisal	30 (100)	88.4–100	30 (100)	88.4–100	30 (100)	88.4–100	30 (100)	88.4–100	30 (100)	88.4–100
Premolar	29 (96.7)	82.8–99.9	29 (96.7)	82.8–99.9	26 (86.7)	69.3–96.2	27 (90.0)	73.5–97.9	24 (80.0)	61.4–92.3
Molar	23 (76.7)	57.7–90.1	17 (56.7)	37.4–74.5	14 (46.7)	28.3–65.7	14 (46.7)	28.3–65.7	9 (30.0)	14.7–49.4
> 55 years										
Incisal	29 (96.7)	82.8–99.9	29 (96.7)	82.8–99.9	29 (96.7)	82.8–99.9	29 (96.7)	82.8–99.9	29 (96.7)	82.8–99.9
Premolar	29 (96.7)	82.8–99.9	28 (93.3)	77.9–99.2	26 (86.7)	69.3–96.2	28 (93.3)	77.9–99.2	24 (80.0)	61.4–92.3
Molar	22 (73.3)	54.1–87.7	15 (50.0)	31.3–68.7	10 (33.3)	17.3–52.8	10 (33.3)	17.3–52.8	9 (30.0)	14.7–49.4
Relationship between fitting and age ^b										
	OR, 95% CI	<i>P</i> -value	OR, 95% CI	<i>P</i> -value	OR, 95% CI	<i>P</i> -value	OR, 95% CI	<i>P</i> -value	OR, 95% CI	<i>P</i> -value
Incisal	0.87, 0.71–1.06	0.153	0.87, 0.71–1.06	0.153	0.87, 0.71–1.06	0.153	0.87, 0.71–1.06	0.153	0.87, 0.71–1.06	0.153
Premolar	0.99, 0.93–1.06	0.776	0.98, 0.92–1.04	0.479	0.99, 0.96–1.04	0.858	1.01, 0.97–1.05	0.696	0.99, 0.96–1.02	0.485
Molar	0.99, 0.96–1.02	0.414	0.98, 0.95–1.00	0.075	0.97, 0.95–0.99	0.041	0.97, 0.95–0.99	0.041	0.98, 0.95–1.01	0.113

CI, confidence interval; OR, odds ratio.

^aNumber and percentage (%) of patients fulfilling the fitting requirements.

^bResults from simple binary logistic regression for the outcome fitting by age of the patient.

reduced the probability of fitting by 3% (OR 0.97, 95% CI 0.95–0.99; $P = 0.041$). In the incisal area (OR 0.87, 95% CI 0.71–1.06; $P = 0.153$) and premolar area (OR 0.99, 95% CI 0.96–1.04, $P = 0.858$ for maxilla; OR 1.01, 95% CI 0.97–1.05, $P = 0.696$ for mandible), no association was detected (Table 2). Fig. 4 illustrates the overall fitting rate according to the implant system and mouth region.

Discussion

This observational, cross-sectional clinical study demonstrated that mouth opening is a clear limitation in the fully guided approach for dental implant placement in a large number of patients. This limitation was most pronounced for the posterior area in the older age group of patients: the mouth opening requirement for the molar site would not be met by 26.7%, 50%, 66.7%, and 70% of patients aged > 55 years when employing the fully guided implant systems of MIS Dentsply, Dentium, Straumann, and Astra Tech Dentsply, respectively.

The study findings are in line with those of a previous prospective cohort study by the present authors' group published in 2022, in which mouth opening was reported as the main limitation of fully computer-guided surgery in the posterior area.⁶ In that previous study, limited mouth opening led to at least one implant in the premolar or molar region being drilled or positioned free-hand in 17.5% of the study sample. Accordingly, other studies have shown greater limitations in employing computer-assisted implant planning and placement in partially edentulous patients, with implant bed preparation and insertion not fully completed in 45.8% and 47.8% of patients treated with two different protocols.¹⁴

Nevertheless, the benefits of using static fully guided surgery to place dental implants have been widely reported, namely enhanced implant positioning accuracy between the 3D preoperative plan and final clinical implant position, which may reduce the risk of aesthetic, prosthetic, and overall long-term complications.^{15–17} Moreover, patient morbidity is reportedly

reduced, and patient satisfaction improved, when a fully guided approach is used in flapless surgeries.^{18–20} However, a substantial number of patients cannot experience the advantages of fully guided surgery because of mouth opening limitations. Thus, free-hand approaches must be performed, thereby increasing the incidence of complications and the overall number of implant positioning errors.²¹

In this study, patients in G3 (> 55 years of age) had lower mean maximum opening measurements in all three areas of the mouth. This finding is in agreement with the data reported by Gallagher et al.,²² indicating that maximum mouth opening decreases with age. As people age, muscle strength decreases, resulting in decreased elasticity; this then limits the movement of both the muscles and ligaments of the temporomandibular joint.²³ However, this age limitation was found not to affect patient suitability for fully guided implant placement in the incisal area in the present study, as this surgery was deemed appropriate in all but one patient, for all four of the implant systems. The incisal area is more accessible

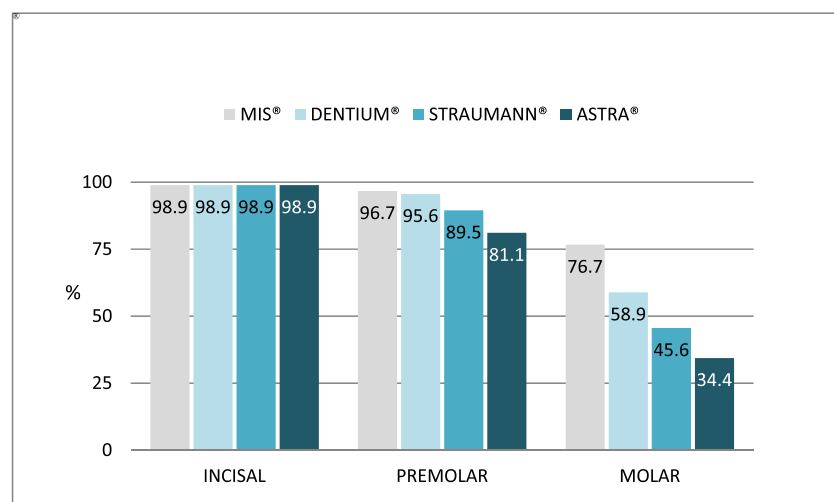


Fig. 4. Overall fitting rate by implant system and mouth region.

and has the higher range of mouth opening. When considering the pre-molar area, the percentage of patients with the minimum required distance for a fully guided surgical approach ranged from 80% (G2 and G3 with the Astra Tech Dentsply implant system) to 96.7% (all groups with MIS Dentsply, and G1 and G2 with Dentium). However, in the molar area only 30% of G2 and G3 patients were deemed suitable for the fully guided approach with the Astra Tech Dentsply implant system, and 33.3% of G3 with the Straumann system.

Regarding the decreased mouth opening associated with patient age, tooth loss seems to decrease mouth opening, and maintaining the dentition in good condition in advancing age will preserve oral function and allow wider mouth opening.²⁴ Other factors such as sex and temporomandibular disorders have also been reported to significantly influence mouth opening limitations.^{25–27}

The current study findings emphasize the fact that a high percentage of patients requiring implants in the posterior area, especially those in the older age group (> 55 years), would not be able to undergo a fully guided implant placement approach as a consequence of mouth opening limitations. Clinicians should be aware that a high percentage of patients (ranging from 20% to 70%, depending on the implant system employed), may not be candidates for fully guided implant placement surgery in the molar region.

In an attempt to reduce the data heterogeneity, this study only considered the minimum distance required

to allow the bone drilling sequence using a static fully guided approach and not the minimum distance required for the fully guided implant insertion. This was done with the understanding that although the distance required for the fully guided implant placement using the contra-angle device with the respective fully guided implant driver could be greater than the distance required for the bone drilling sequence, a manual fully guided implant insertion could also be employed, reducing the need for wider mouth opening during this surgical step.

This observational study has some limitations. The maximum mouth opening of the patients was assessed at one specific time point and was not obtained throughout the surgery. Hence, the actual mouth opening maintained throughout the surgery is likely less than that reported here. In addition, this study only considered the shortest fully guided drill from each implant manufacturer, and for MIS Dentsply, Astra Tech Dentsply, and Dentium systems, the shortest drill is only used for placement of a 6-mm long implant. Moreover, angle variations will affect the suitability of the candidates for fully guided surgery. Unfortunately, this variable is difficult to evaluate due to the particularity of each participant. Therefore, when considering the placement of implants longer than 6 mm, mouth opening limitations may result in an even lower percentage of patients suitable for fully guided surgery.

In conclusion, despite the many advances in oral implantology, digital

dentistry, and guided surgery, mouth opening remains a major limitation for fully guided implant surgeries, especially in posterior areas in older patients. Clinicians should be aware that some implant systems may allow fully guided implant placement in the posterior area in only one out of three patients. As mouth opening is not modifiable, future research in guided surgery should focus on reducing the dimensions of the system to increase patient suitability for guided surgery.

Ethical approval

This study was approved by the Ethics Committee for Research of the International University of Catalonia (CIR-ECL-2019-07).

Patient consent

Obtained.

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Declaration of Competing Interest

The authors declare that they do not have any financial interests, either directly or indirectly, in the products or information listed in the entire manuscript.

Declaration of Generative AI and AI-assisted technologies in the writing process

The authors confirm that they have not used generative AI or AI-assisted technologies in any of the writing process.

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