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Survival of dental implants placed in a postgraduate educational setting: a retrospective cohort study

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ABSTRACT

Introduction: Dental implant treatment can still fail due to various factors. The aim of this retrospective cohort study was to assess the influence of operator experience in a postgraduate educational setting, as well as patient, implant, and surgical risk factors on the incidence of the dental implant failure.

Methods: The dental records of 1049 implants with a mean follow-up of 794.70 days were analysed. Variables included operator experience (year of specialty study) and clinic-pathological patients' related variables. Clinic-pathological associations were explored and a Cox regression model accounted for implant survival factors.

Results: Multivariate analysis revealed that a history of periodontitis and smoking were the only factors with independent prognostic value, with hazard ratios of 2.0 (95 % CI: 1.0–4.0, $p = 0.048$) and 1.9 (95 % CI: 1.0–3.6, $p = 0.039$) respectively. Conversely, despite implant treatment delivered by early career students had a higher failure rate (5.6 %) compared to advanced career students (3.7 %), this difference was statistically significant only in the univariate analysis.

Conclusion: Periodontitis and smoking are independent prognostic variables, with career level potentially biasing complex case allocation to advanced students. Targeted educational interventions, including virtual reality and artificial intelligence, should be emphasized in student training. University-based implant trials must consider operator career stage.

Clinical significance: The study underscores the importance of operator experience in dental implant success. It highlights that while clinical experience influences outcomes, factors like a history of periodontitis and smoking are independent predictors of implant failure. These findings emphasize the need for targeted educational interventions to improve clinical training and patient outcomes.

1. Introduction

Dental implants have become a reliable and predictable option for patients with missing teeth. Recent analyses forecast that the global dental implant market will grow at a compound annual rate of 9.8 % from 2024 to 2030, driven by increasing demand for therapeutic applications among an aging population [1,2]. Despite a high success rate of approximately 96.4 % at 10 years [3], implant failures still occur, significantly impacting clinical outcomes and patient satisfaction [4]. Implant failure is defined as the inability of an implant to fulfill its functional or aesthetic purpose due to biological reasons, such as inadequacies in maintaining osseointegration, or mechanical reasons, including fractures of implants, coatings, connecting screws, and prostheses [5].

Implant failure can be broadly categorized into early and late failures [6]. Early failures are characterized by the inability to achieve osseointegration, the process by which bone forms a direct interface with the implant surface [1,7]. Conversely, late implant failures occur

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after osseointegration has been established and are often attributed to factors such as peri-implantitis and subsequent loss of supporting bone [8].

A recent study by Staedt et al. [9] on 9080 implants shows that early failures were more frequent than late failures, with frequencies of 83.48 % and 16.52 %, respectively. Several factors can cause implant failure, but the most significant are related to the patient and the operator [8]. Patient-related factors, such as smoking history, periodontal disease, and systemic disorders (e.g., uncontrolled diabetes), increase the risk of infection and impaired healing, leading to implant failure [10,11]. Additionally, patients with osteoporosis may experience increased implant failure due to reduced bone quality and quantity, with up to 35 % of implant failures occurring in type IV bone [12]. Operator-related factors, such as the choice of surgical technique [13], implant site, and implant design, significantly influence the success rate of dental implants [14,15]. Inadequate irrigation and bone overheating during site preparation can lead to necrosis and impaired osseointegration [13,16,17]. The surgical protocol and implant site also impact failure risk, with two-stage surgical protocols and lower jaw placements having a higher failure risk compared to one-stage procedures and maxillary placements [18–20]. Implant design, such as length and diameter, is another critical operator-related factor, though it remains controversial in the literature [21–23]. Longer implants often result in higher success rates due to increased bone-to-implant contact, providing better mechanical stability [24]. However, excessively long implants may predispose to failure due to bone overheating during preparation [25]. Similarly, wider implants increase the contact surface area, enhancing resistance to occlusal forces [26].

Planning the implant position is a critical step, as being definitive, in order to obtain the same benefits of prosthetic planning, and to facilitate numerous prosthetic aspects that often represent the problem, especially in the number of complications and in their clinical definition of long-term success [27,28].

In the medical field, more research has focused on the operator experience, highlighting that surgical experience can significantly improve efficiency and outcomes [29,30]. The experience and surgical skills of the clinician are crucial for the success or failure of dental implants, making it important to evaluate the impact of education and accumulated experience on implant survival rates [31]. Considering that many published studies on implant dental treatment outcomes have been performed in educational settings, such as universities, the operator experience may represent an underestimated variable. Nowadays, studies on the influence of operator experience and skill level on dental implant outcomes are few and inconclusive, indicating gaps in the literature [2,31,32]. Therefore, this study aims to investigate whether operator experience significantly affects successful implant placement. Specifically, it will examine the incidence of implant failures among postgraduate students at Griffith University and assess the impact of operator experience on these failures.

2. Materials and methods

This study was approved by the Griffith University Human Research Ethics Committee (GU Ref No: 2019/119). A non-interventional retrospective cohort design was employed, and all data were analysed anonymously.

Data were collected at implant level based on inclusion criteria, as listed; 1. of patients who underwent dental implant treatment in a partial edentulous maxilla/mandible; 2. aged over 18 years old; 3. who were treated at the institution; 4. by a postgraduate student enrolled in the specialist postgraduate periodontal and implant clinic program; 5. whom operator code was possible to retrieve; 6. patients had to be followed for more than 10 days.

Patients not fulfilling these requirements, for which outcome was not retrievable or were pregnant or reported a history of cancer or active periodontal disease, were excluded from this study. Moreover, implants placed outside of the Institution and patients who missed follow-up appointments were excluded from the study. No restrictions were added upon implant characteristics, smoking history, periodontal and bone disease history, history of diabetes and bone augmentation procedures. These variables were also collected and their role on the main outcome was also statistically addressed. These records were accessed by authorized personnel. Both implants with early failure, defined as "implants with signs of impaired healing and/or treated for infection resulting in implant loss before the final restoration" and implant lost during the consequent follow-ups, were identified by reviewing the clinical notes of each participant.

2.1. Data collection

Sample size calculation was performed based on the results from a previous study where implant failure was tested in a postgraduate setting according to practitioners' experience (<50 implants), which led to 8/50 and 12/215 failed implants in each group [33]. These proportions were input into G*Power 3.1.9.7. software under *z* tests, a priori sample size computation, two tails based set up on proportions of representative groups and an α value of 0.05 and a β value of 0.95 [34]. This resulted in a total sample size of 448, with a minimum of 224 per group. In this study, inexperience was evaluated by 50 implant surgeries cut-off, leading to 457 implants into the inexperienced groups versus 592, and by year of study cut-off, with 622 inexperienced versus 427.

Participants' medical history and dental records were collected. The following variables were identified and recorded on a data collection spreadsheet, such as year level of the postgraduate student placing the implant (year 1, 2, or 3), age of the patient at implant surgery, patient's sex, implant length and width, implant location (anterior vs. posterior and maxillary vs. mandibular), the occurrence of bone augmentation at implant placement, and whether the patient had a history of periodontal disease, smoking, diabetes and bone disease.

2.2. Statistical analyses

All analyses were performed at the implant level. Associations with patient-related factors were explored using the Chi-Square test. The only linear variables were age, implant width, and length. As these tested statistically significant (p-value <0.001) for the Shapiro–Wilk test of normality, non-normal distribution was assumed, and Mann–Whitney or Kruskal–Wallis tests were employed to investigate differences among these variables and patient-related factor groups. A univariate Kaplan–Meier time-dependent model was built to investigate whether the year of experience and specialty of the operator could impact the failure of the implant treatment. Failure was defined as implant loss at any time during the follow-up, without distinguishing between early and late failures. Variables affecting implant survival in the univariate analysis were included in a multivariate Cox regression model to investigate independence. Based on the total number of implant treatments performed, students were also compared as operator with ≥50 implant treatments versus <50. These tests were performed using SPSS v.25, and a p-value <0.05 was considered statistically significant.

3. Results

3.1. Patient-related factors

Patients were followed for an average of 794.43 days (SD = 902.01), with a minimum and maximum follow-up of 11 and 4413 days, respectively.

Information were collected from 1456 implants placed between 2008 and 2018 by postgraduate students enrolled in the specialist postgraduate periodontal and implant program at Two hundred ninety-six cases were excluded due to missing outcome information. Additionally, 110 cases were eliminated because their follow-up information was less than 10 days. One case was eliminated because the experience of the operator was not retrieved. Consequently, a total of 1049 implants were included in the final analysis.

All included implants were placed in patients over the age of 18 years old, with comprehensive electronic medical and dental records permanently stored within the Patient Management System "Titanium" at the Specialist Postgraduate Periodontal and Implant Clinic, Griffith University, Gold Coast.

Overall, 4.9 % of implant treatments failed (51 out of 1049) (Table 1), resulting in a total survival rate of 95.1 % (998 implants). The mean age of the patients was 56.65 years (SD = 13.1). Implants were placed in the maxilla in 53.8 % (564) of cases and in the mandible in 45.9 % (481) of cases, with 33.9 % (356) in the anterior region and 65.7 % (689) in the posterior region. Of these, 60.2 % (632) were planned as one-stage procedure, while 39.5 % (414) were two-stage procedure.

Regarding other clinical variables, 52 % (545) of implant sites did not undergo a bone augmentation procedure, whereas 45.7 % (479) were placed in regenerated bone. Close to half of the patients (47.5 %, 498) had a history of periodontitis, and only 5.3 % (56) and 4.3 % (45) reported a positive history of diabetes and bone disease, respectively. Additionally, 42.2 % (443) of patients reported a history of smoking. Most implants were placed by periodontology specialty students in their 2nd year of studies (46.1 %, 484), followed by students in their 3rd year (40.7 %, 427). Among the 51 failed implants, 30 were positioned by students in their 2nd year of implantology specialization (6.2 %) and 2 (3.3 %) were positioned by students in their 1st year of periodontology specialization. Only 7 implants were positioned by implantology students in their 1st year (0.7 %) without failures. To account for this distribution, students were grouped regardless of their specialization course into 1st and 2nd year (early career) versus 3rd year students (advanced career). The age of patients did not significantly differ between the two groups (Mann–Whitney, *p*-value = 0.272). Advanced career students placed shorter and thicker implants (Mann–Whitney, *p*-values = 0.013 and < 0.001, respectively), with a mean length of 8.57 mm (SD = 1.98) and a mean width of 4.76 mm (SD = 0.68). Of the 622 implants placed by early career students, 35 failed (5.6 %) compared to 16 (3.7 %) placed by advanced career students. No differences were observed regarding patient sex, with 55.8 % (346) and 55.7 % (238) of females being treated by early and advanced career students, respectively (Chi-square test, *p*-value = 0.982). Statistically significant differences were observed in the anatomical characteristics of the implant treatments: most of patients treated by advanced career students received implants in the posterior maxilla (42 %, 139), while early career students more frequently treated the posterior mandible (65.6 %, 235) (Chi-square test, *p*-value = 0.010). Advanced career students used a one-stage protocol in 70.9 % (302) of cases, compared to 53.2 % (330) by early career students (Chi-square test, *p*-value <0.001). There were no differences in bone augmentation procedures between the groups (Chi-square test, *p*-value = 0.146). Regarding patient-related factors, patients treated by early and advanced career students were similar in distribution, with no differences in the history of periodontal disease (Chi-square test, *p*-value = 0.271), diabetes (Chi-square test, *p*-value = 0.207), bone disease (Chi-square test, *p*-value = 0.604), and smoking history (Chi-square test, *p*-value = 0.997). A detailed distribution of these patient-related factors between early and advanced career students is summarized in Table 2.

Table 2
Clinical characteristics of patients treated by early and advanced career students (*p*-value from Chi-square test).

Patients' variables		Early career students	Advanced career students	*p*-value
Sex	Male	274 (44.2 %)	189 (44.3 %)	0.982
	Female	346 (55.8 %)	238 (55.7 %)	
Implant location	Anterior maxilla	121 (19.5 %)	112 (26.4 %)	0.01
	Anterior mandible	73 (11.8 %)	50 (11.8 %)	
	Posterior maxilla	192 (30.9 %)	139 (32.8 %)	
	Posterior mandible	235 (37.8 %)	123 (29.0 %)	
Implant stage treatment	One stage	330 (53.2 %)	302 (70.9 %)	<0.001
	Two stages	290 (46.8 %)	124 (29.1 %)	
Bone augmentation	None	335 (55.1 %)	210 (50.5 %)	0.146
	Yes	273 (44.9 %)	206 (49.5 %)	
History of periodontitis	None	234 (42.8 %)	161 (46.5 %)	0.271
	Yes	313 (57.2 %)	185 (53.5 %)	
History of diabetes	None	565 (95.0 %)	346 (93.0 %)	0.207
	Yes	30 (5.0 %)	26 (7.0 %)	
History of smoking	None	326 (54.6 %)	207 (54.6 %)	0.997
	Yes	271 (45.4 %)	172 (45.4 %)	
History of bone disease	None	567 (95.6 %)	353 (94.9 %)	0.604
	Yes	26 (4.4 %)	19 (5.1 %)	

Table 1
Grouped characteristics of lost implants (detailed specification for each lost implant is represented in supplemental Table 1).

Months at failure	n#	Operator experience	n#	Sex	n#	Anatomy	n#	Bone augmentation	n#	Stage	n#
6	21	Operator put <50 implants	18	Male	32	Anterior maxilla	15	No	21	1 stage	33
12	10	Operator put≥50 implants	33	Female	19	Anterior mandible	5	Yes	29	2 stage	17
18	4	First/second year	35	**Age**	**n#**	Posterior maxilla	16	Missing	1	Missing	1
24	1	Third year	16	20–30	4	Posterior mandible	15	**Hist. periodontal disease**	**n#**	**Width**	**n#**
30	3			40–59	15			No	11	≤3.5	3
36	4			60–80	32			Yes	33	>3.5	48
42	4							Missing	7		
>70	4							**Hist. Diabetes**	**n#**	**Length**	**n#**
								No	42	<10	30
								Yes	4	≥10	21
								Missing	5		
								Hist. bone disease	**n#**		
								No	43		
								Yes	3		
								Missing	5		
								Hist. smoking	**n#**		
								No	18		
								Yes	29		
								Missing	4		

3.2. Survival analysis

Kaplan–Meier analysis showed statistically significant results for sex (*p*-value = 0.013), experience of the students (early vs. advanced career) (*p*-value = 0.05), history of periodontitis (*p*-value = 0.013), and history of smoking (*p*-value = 0.014). Implant width nor length were associated to dental failure (respectively, hazard ratio (HR) of 0.826, 95 % 0.498–1.371, $p = 0.460$ and 1.063, 95 % 0.871–1.297, $p = 0.549$).

Statistically significant variables were modelled in a Cox regression multivariate analysis. The multivariate analysis indicated that only the history of periodontitis and smoking had independent prognostic value. Patients with a history of periodontitis had a HR of 2.008 (95 % CI: 1.005–4.010, $p = 0.048$), while those with a history of smoking had an HR of 1.930 (95 % CI: 1.034–3.602, $p = 0.039$). Sex was close to statistical significance, with females at lower risk of implant loss (*p*-value = 0.079). Implants placed by early career students were more likely to fail, although this was close to the statistically significant threshold (HR = 1.811, 95 % CI = 0.939–3.493, *p*-value = 0.076) (Fig. 1). Number of implant treatments performed, 50 implants as cut-off value to differentiate students on their experience, did not result in a statistically significant difference relative to overall implant survival (<50 implants HR = 0.724, 95 % CI = 0.407–1.288, $p = 0.274$) (Table 3).

Table 3
Overall percentage of implants failed based on student career level and number of implant treatments performed based on a cut-off value of 50 implants. Treatments performed by early career students with more than 50 implants reported lowest overall success percentage.

Career early_advanced	Experience, cut-off 50 implants	Total implants	Failed implants	Overall Survival %
Early career	<50 implants	325	13	96.0 %
	≥50 implants	297	22	92.6 %
Advanced career	<50 implants	132	5	96.2 %
	≥50 implants	295	11	96.3 %
Total		1049	51	95.1 %

4. Discussion

The overall survival rate of implants in this cohort was 95.1 %, aligning with the high success rates reported by other studies and with a recent systematic review, which estimated an implant success rate of 96.4 % [3,35]. Notably, early career students had a higher failure rate (5.6 %) compared to advanced career students (3.7 %), although this difference was not statistically significance in the multivariate analysis (*p*-value = 0.076). This trend suggests that clinical experience might play a critical role in implant success, a finding consistent with previous studies emphasizing the impact of clinician expertise on implant outcomes [32], but in clinical settings.

Patient-related factors such as age, sex, history of periodontitis, diabetes, bone disease, and smoking habits were evaluated for their influence on implant success. The mean age of patients was 56.65 years, with a balanced sex distribution between patients treated by early and advanced career students.

The multivariate survival analysis revealed that patients with a history of periodontitis were 2 times more likely to undergo implant failure. Similarly, smoking was associated with a worse outcome. These findings confirm existing evidence that periodontitis and smoking are significant risk factors for implant failure due to their adverse effects on peri-implant tissue health and osseointegration [36,37].

Regarding the experience and education level of the students, the multivariate analysis demonstrated no statistically significant difference between early and advanced-career students, in agreement with the existing literature [38–40]. Although this result might seem counterintuitive, it is important to note that our assessment of experience was based on students during their specialty career and stage of their training and not on the number of implants placed [15], as previous studies did. The influence of surgical experience on implant survival has been demonstrated by several authors using different methods to classify surgeons as experienced or not. Among these, the most used criteria were the year of stage training, or the total number of implants placed. Considering that the initial or final phase of training does not seem to be a reliable criterion since, regardless of time, a professional can perform more or less implant treatments as highlighted by Di Melo et al. [41], with the number of 50 implants placed, which seems to be a more predictive measure [33]. Indeed, Sendyk et al. indicated that surgical experience did not significantly affect implant failure rates when considering experience based on specialty, but it did have a significant effect when considering experience based on the number of implants placed. However, these studies included specialists and experienced surgeons, and in only two studies, these were differentiated based on

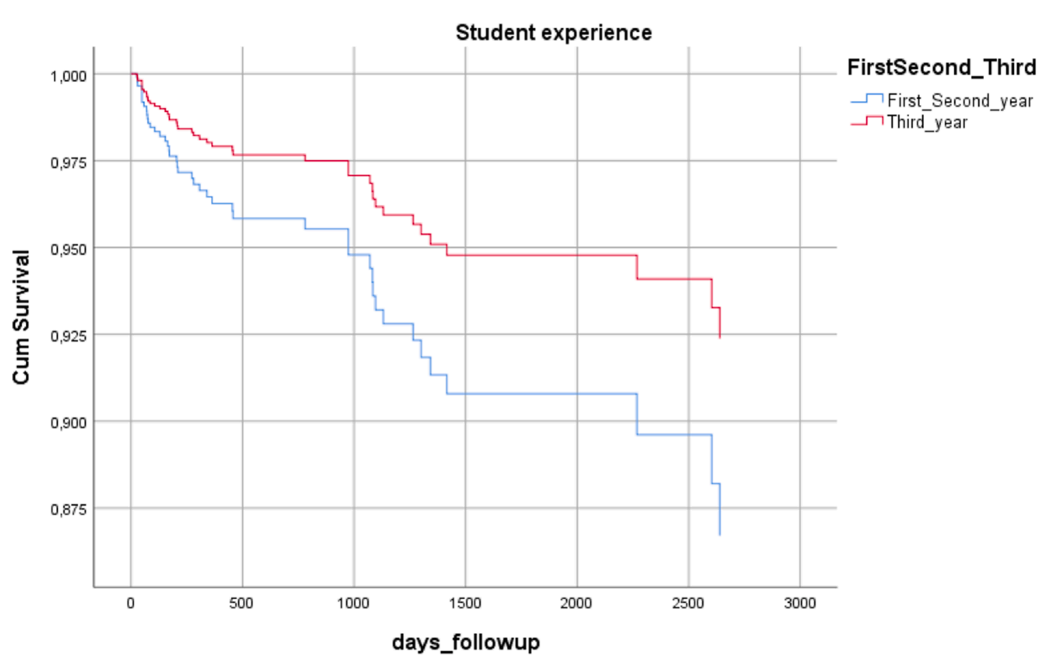

Fig. 1. Kaplan–Meier curves for implant survival (*p*-value = 0.05) based on students' experience.

number of implants placed, but still specialists, even with more than 5 years of experience. Our study is the first evaluating the role of the experience in an educational setting with both dividing specializing students based on year of study and number of implants. In addition, the previous studies analysed the data as event/total number at fixed time-points without considering survival as time-dependent event and implant treatment stage. Indeed, in our study log rank and Cox regression analysis were performed, which consider both the time-dependent nature of failure, which follows the implant treatment stage (positioning, load to function) and the role of the confounding factors, which were not in deep evaluated in the previous studies, based on the systematic review report [42]. Results from our study indicated that implant treatment experience, based on the number of implant treatments performed in an educational setting, did not show a statistically significant difference.

It is reasonable to hypothesize that students in advanced years of specialization have placed a greater number of implants, which could explain why, despite not reaching statistical significance, the multivariate analysis approached the threshold for significance (HR = 1.801, 95 % CI = 0.934–3.474, $p = 0.079$). Conversely, the Kaplan–Meier survival analysis indicated that implants placed by advanced career students had a higher survival rate, with statistical significance at $p = 0.05$. This result comes from the fact that this statistical analysis only considers the surgeons' experience and not patient-related factors, suggesting that advanced career students could probably operate on more complex patients. This was confirmed by the statistically significant differences in implant dimensions between early and advanced career students (anatomical location, length and width). This latter finding underscores the importance of experience in clinical decision-making and surgical execution. Sex appeared to influence implant survival, with females exhibiting a lower risk of implant loss ($p = 0.079$), though this result did not reach statistical significance. Previous studies have presented mixed results regarding the impact of sex on implant outcomes, with some suggesting that females may have higher dental implant success rates due to better oral hygiene practices, lower incidence of periodontitis, and generally lower bite force compared to men, reducing implant overload risk [43]. The minimal significance observed in this study suggests the need for further investigation with a larger sample size to clarify potential sex-related differences in implant survival. Anatomical features of implant sites also influenced treatment outcomes. Advanced career students more frequently treated patients requiring posterior maxillary implants compared to early career students, who primarily managed posterior mandibular implants. The posterior maxilla presents unique challenges due to its lower bone density and proximity to the sinus, potentially requiring advanced surgical skills [44]. The significant difference in the anatomical site of implant placement between student groups ($p = 0.010$) highlights the need for customized training programs that address the complexities of different implant sites. Additionally, the preference for one-stage protocols by advanced career students compared to early career students reflects evolving trends in implant dentistry toward more efficient treatment protocols. One-stage procedures, when appropriately indicated, can reduce patient visits and overall treatment time, contributing to greater patient satisfaction and potentially improved outcomes [18,45]. Recently, there has been a rapid growth in research conducted around the risk factors associated with implant failure. However, the influence of operator experience has not been sufficiently investigated. As this is a pioneering study in this field, there are several limitations to consider. Although the study considered several patient-related factors, including age, sex, history of periodontitis, diabetes, bone disease, and smoking habits, other potentially influential factors were not considered. The mean follow-up period of approximately 2 years provides important information on the medium-term outcomes of dental implants, longer follow-up periods are needed to fully understand the long-term survival rates of implants. Additionally, this study did not assess the level of patient adherence to follow-up protocols or their engagement in recommended oral hygiene practices, potentially affecting the results.

These findings emphasize the need for targeted educational interventions, highlighting the importance of skill development in achieving optimal outcomes. This should be considered in light of the new educational means, such as virtual reality and artificial intelligence, which might become a strong core curriculum for student practitioners, before approaching patients.

5. Conclusion

History of periodontitis and smoking represented independent prognostic variables, outstanding the student career level. This result might be the consequence of biased patient allocation for more complex cases to advanced career students.

Operator career stage should be considered in university-based implant treatment trials.

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CRediT authorship contribution statement

Vito Carlo Alberto Caponio: Writing – original draft, Software, Methodology. **Ajay Sharma:** Data curation, Conceptualization. **Gennaro Musella:** Writing – original draft, Formal analysis, Data curation. **Vittoria Perrotti:** Writing – review & editing, Supervision, Conceptualization. **Alessandro Quaranta:** Writing – review & editing, Project administration, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no conflict of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jdent.2024.105531.

Data availability

The data that support the findings of this study are available from the corresponding author, Prof. Vittoria Perrotti, upon reasonable request. All relevant data are included within the article and its supplementary information files.

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