



**HAL**  
open science

## **Knowledge in Oral Infectiology and Antibiotic Stewardship of French Dental Students: A National Cross-Sectional Survey**

Marie-louise Constant, Antoine Kimmoun, Alexandre Baudet, Benjamin Lefèvre, Nathalie Thilly, Maïa Simon, Julie Guillet-Thibault

### ► **To cite this version:**

Marie-louise Constant, Antoine Kimmoun, Alexandre Baudet, Benjamin Lefèvre, Nathalie Thilly, et al. Knowledge in Oral Infectiology and Antibiotic Stewardship of French Dental Students: A National Cross-Sectional Survey. *European Journal of Dental Education*, 2025, <10.1111/eje.13092>. <hal-05076930>

**HAL Id: hal-05076930**

**<https://hal.science/hal-05076930v1>**

Submitted on 22 May 2025

**HAL** is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons CC BY 4.0 - Attribution - International License

1 **Knowledge in oral infectiology and antibiotic stewardship of French**  
2 **dental students: a national cross-sectional survey**

3 Marie-Louise Constant<sup>1</sup>, Antoine Kimmoun<sup>2,3</sup>, Alexandre Baudet<sup>1,4</sup>, Benjamin  
4 Lefèvre<sup>5,6</sup>, Nathalie Thilly<sup>4,7</sup>, Maïa Simon<sup>4,7\*</sup>, Julie Guillet-Thibault<sup>1\*</sup>

5 \* Last co-authors, contribute equally to this work

6 <sup>1</sup> Université de Lorraine, CHRU-Nancy, Service d'Odontologie, F-54000 Nancy,  
7 France

8 <sup>2</sup> Université de Lorraine, CHRU-Nancy, Service de Médecine Intensive et  
9 Réanimation, F-54000 Nancy, France

10 <sup>3</sup> Université de Lorraine, Inserm u1116, FCRIN INI CRCT, F-54000Nancy, France

11 <sup>4</sup> Université de Lorraine, APEMAC, F-54000 Nancy, France

12 <sup>5</sup> Université de Lorraine, CHRU-Nancy, Département de Maladies Infectieuses et  
13 Tropicales, F-54000 Nancy, France

14 <sup>6</sup> Université de Lorraine, INSERM, INSPIIRE, F-54000 Nancy, France

15 <sup>7</sup> Université de Lorraine, CHRU-Nancy, Département Méthodologie Promotion  
16 Investigation, F-54000 Nancy, France

17

18 Corresponding author: Marie-Louise CONSTANT, Department of dentistry. Nancy  
19 Regional University Hospital. Rue du Morvan. 54500 Vandoeuvre-lès-Nancy. France.

20 E-mail : [marielouiseconstant@gmail.com](mailto:marielouiseconstant@gmail.com), Phone : +33678033359

21

## 22 **Abstract**

23 **Introduction:** Several studies highlighted a lack of knowledge of dentists concerning  
24 antibiotic stewardship. The objectives of this study were to evaluate dental student's  
25 level of knowledge in infectiology and antibiotic stewardship, and to identify factors  
26 associated with a high level of knowledge.

27 **Materials and methods:** A cross-sectional national multicenter survey was conducted  
28 in 2022-2023 through a self-administered and internet-based questionnaire. A  
29 knowledge score (out of 34) was calculated for each included student based on their  
30 questionnaire results. Hierarchical clustering methods were used to identify clusters of  
31 students according to their knowledge score. This approach highlighted distinct score  
32 levels. A logistic regression model was then applied to associate specific factors with  
33 these levels. The association between the cluster of students with the highest  
34 knowledge and the characteristics of the students and their faculties was assessed  
35 using logistic regressions.

36 **Results:** A total of 415 students were included. Two clusters were identified: the cluster  
37 "average level of knowledge" included 290 (70%) students (median knowledge score:  
38 26/34, IQR: 24;27), while the cluster "high level of knowledge" grouped 125 (30%)  
39 students (median knowledge score: 30/34, IQR: 29;32). Mandatory courses and  
40 multiple learning modalities were associated with higher knowledge.

41 **Conclusion:** French dental students seem to have a high knowledge in infectiology and  
42 antibiotic stewardship, as evidenced by the median knowledge score of each cluster,  
43 which are objectively high compared to the maximum of 34. We identified several  
44 factors associated with a higher knowledge that might help conceiving learning  
45 modalities standardized recommendations.

46 **Keywords**

47 Cluster analysis, dental education, antimicrobial stewardship, students, knowledge

48

49 **In brief:**

50 - This is the first French national study to evaluate dental students' knowledge in  
51 infectiology and antibiotic stewardship.

52 - This study will guide the future standardization of infectiology courses at a  
53 national level. These findings could, therefore, be implemented in the policy for  
54 curriculum development in dental education.

55 - A hierarchical clustering method was used to identify distinct score levels. In  
56 this study, a logistic regression model associated mandatory courses with the  
57 cluster "high level of knowledge".

58

59 **Introduction**

60 Antibiotic resistance is a global public health issue highlighted by the World Health  
61 Organization (WHO) since 2014<sup>1</sup>. Without preventative measures, it is estimated that  
62 by 2050, antibiotic resistance could become the world's primary cause of death with  
63 10 million deaths per year.<sup>2</sup> Antibiotic resistance is accelerated by unnecessary (i.e.  
64 prescribing antibiotics in the absence of a bacterial infection or appropriate medical  
65 indication) and inappropriate antibiotic use (i.e. prescription of antibiotics that does not  
66 respect optimal dosage, duration or does not target the specific bacteria). These two  
67 kinds of misuses are frequently encountered in dental practice and contribute to the  
68 increase of antibiotic resistance.<sup>3</sup> It is well established that the treatment of  
69 odontogenic infections primarily relies on surgical intervention. However, in case of  
70 systemic involvement, the use of antibiotic therapy is recommended. Yet, the use of  
71 these antibiotics in dentistry, in case of odontogenic infections, has been linked to the  
72 development of antibiotic resistance. Notably, penicillin is the first-line antibiotic used  
73 in dentistry and is a key contributor to antibiotic resistance. These facts highlights the  
74 need to adapt prescriptions to the clinical situation, its progression, and the  
75 guidelines.<sup>4-6</sup> Dentistry is the only medical specialty for which the quantity of antibiotic  
76 prescriptions has increased in the last decades in France.<sup>7</sup> Several studies showed  
77 that dentists' prescriptions are often not in line with recommendations in Europe,<sup>8-10</sup>  
78 and notably among French dentists where 11.6% prescribed inappropriate  
79 antibiotics.<sup>11</sup> The lack of clear up-to-date guidelines, insufficient educational programs  
80 on antibiotic prescription, and the absence of correlation between dentists' theoretical  
81 knowledge and their prescribing practices (which relies more on experience than actual  
82 knowledge)underscores the need to further investigate these factors to ensure proper  
83 antibiotic use and combat antibiotic resistance.<sup>12</sup>

84 In France, dental education is based on 6 years of training, with the 6<sup>th</sup> year being the  
85 final year of dental school. During this year, students are expected to possess the  
86 highest level of knowledge, and as they can practice and prescribe as part of a  
87 supervised internship, they already have a significant impact on public health.  
88 However, non-standardized infectiology training in French dental faculties results in  
89 knowledge gaps. Several comparative studies or cross-sectional surveys showed a  
90 lack of knowledge of healthcare students concerning antibiotic stewardship. Most  
91 students recognize antimicrobial resistance as a major public health issue, but on the  
92 other hand, there are improper practices and a significant gap in knowledge. They  
93 prescribe inappropriate antibiotics or use them preventively after extractions to avoid  
94 post-treatment infections. It emphasizes the urgent need to improve education on  
95 antibiotics, especially among young practitioners.<sup>13-15</sup>

96 The educational adaptation and optimization of the dental training in France is part of  
97 the 2022-2025 National Strategy for the Prevention of Infections and Antimicrobial  
98 Resistance in Human Health. This strategy is based on two main axes : infection  
99 control, prevention and raising awareness about antibiotic stewardship, beginning by  
100 stating the global knowledge of the healthcare students.<sup>16</sup>

101 A common core of competencies and minimal knowledge in prevention of infections  
102 and antibiotic resistance for healthcare workers including dentists was published in  
103 December 2022.<sup>17</sup> Assessing dental students' current level of knowledge and  
104 associated factors can be used to improve teaching of oral infectiology and antibiotic  
105 stewardship, which could lead to better antibiotic use.<sup>18-21</sup>

106 The aims of this study were to evaluate final-year dental student's level of knowledge  
107 in oral infectiology and antibiotic stewardship, and to identify students' and faculties'  
108 characteristics associated to a high level of knowledge.

## 109 **Materials and methods**

110

### 111 **Study setting and population**

112 We targeted all 6<sup>th</sup>-year dental students across the 15 French dental faculties during  
113 the 2022-2023 academic year. In France, the 6<sup>th</sup> year of study is the last year of  
114 dentistry education, offering a comprehensive view of the complete odontology  
115 training. In addition to their theoretical learning, they also had a 250-hours internship  
116 supervised by a dental practitioner (mentor). These students start practicing and  
117 prescribing, therefore they can have a significant impact on antibiotic stewardship and  
118 public health. There were 1,285 6<sup>th</sup>-year students during the considered academic  
119 year, averaging 86 students per faculty, ranging from 32 to 210. In France, each dental  
120 faculty have an antibiotic resistance mission manager, responsible for communication,  
121 learning, and research on antibiotic resistance. They were appointed by the deans of  
122 each faculty with the aim of reforming and improving programs in infectious diseases,  
123 as well as standardizing knowledge at a national level. In the context of the present  
124 study, they helped the connection between the study investigator and the 6<sup>th</sup> year  
125 students from each faculty.

### 126 **Survey design and data collection**

127 A cross-sectional national multicentre survey was conducted from December 6, 2022  
128 to February 1, 2023, through a self-administered and internet-based questionnaire  
129 hosted on LimeSurvey®.

130 The development of the 34-item online questionnaire was based on a literature  
131 review,<sup>18-22</sup> antibiotic recommendations,<sup>23</sup> and the basic knowledge a last-year student  
132 should have in antibiotic stewardship according to the modalities knowledge  
133 assessment. The questionnaire was developed and validated by a multidisciplinary

134 group including two hospital and private dentists, a last-year dental student, two  
135 methodologists and an infectious disease specialist. Constructed specifically for this  
136 study, its scientific validity has been examined. In terms of content, the questionnaire  
137 resumes all relevant and essential aspects of oral infectiology and antibiotic  
138 stewardship, including recent and fundamental knowledge. It was based on five topics:  
139 (i) characteristics of the student and his mentors' (e.g. age and activity) (5 items), (ii)  
140 his/her knowledge regarding antimicrobial resistance epidemiology (8 items), (iii)  
141 general infectiology (10 items), (iv) antibiotic prescribing recommendations (11 items),  
142 and (v) five clinical cases (assessment of knowledge with five clinical vignettes  
143 exploring different area of knowledge: infection prevention, preoperative prescriptions,  
144 periodontal disease, facial trauma) (**table S1**). A pre-test was conducted by all  
145 members of the multidisciplinary group, and the questionnaire was validated regarding  
146 the scientific concepts discussed prior to the pilot test, which was pilot-tested by two  
147 dentists to assess its clarity and its relevance.

148 The students received an e-mail from the antibiotic resistance mission manager of their  
149 faculty, inviting them to take part in the study. The mission manager also answered  
150 another questionnaire to describe the different learning modalities of his/her faculty  
151 considering topics related to antibiotic resistance, and the volume of these courses. E-  
152 mail reminders were sent during the third week of December, first and third week of  
153 January, and an ultimate reminder on the January 30, 2023.

154 Every students of each faculty received their e-mail and e-mail reminders as described  
155 chronologically above, confirmed through regular communication with the mission  
156 manager.

157 **Statistical analyses**

158 Categorical variables were presented as numbers and percentages, while continuous  
159 variables were presented as means with standard deviations or medians with  
160 interquartile ranges (IQRs). Students were included in the analyses if they completed  
161 at least the topics (i) and (ii) of the questionnaire (i.e. if they answered at least the first  
162 questions of knowledge). A level of knowledge was estimated for each student using  
163 a knowledge score calculated from their questionnaire results. A correct answer was  
164 equal to one point, a wrong answer to zero. If a student partially responded, its score,  
165 based on the proportion of answered questions, was then scaled to a score out of 34.  
166 This adjustment ensured their inclusion in the appropriate clusters, based on a  
167 standardized score out of 34.

168 Hierarchical clustering was performed using Ward's method to identify groups of  
169 students according to their knowledge score (which reflects their level of knowledge).

170 Bivariate logistic regression analysed the associations between the cluster with "high  
171 level of knowledge" and the students' and faculties' characteristics (determined *a priori*  
172 by consensus from authors). Variables, with p-values < 0.10 in bivariate analyses, were  
173 considered as candidates for the multivariable logistic regression. Multicollinearity  
174 between the candidate variables was assessed before model construction. A backward  
175 stepwise approach was applied to identify the most relevant variables based on their  
176 contribution to minimizing the Akaike Information Criterion (AIC) and their statistical  
177 significance ( $p < 0,05$ ). The selected variables were then included in the final  
178 multivariable logistic regression model to identify independent associations. Odds  
179 ratios (ORs), adjusted ORs (aORs) and 95% confidence intervals (95% CIs) were  
180 reported.

181 Sensitivity analyses using alternative clustering methods (k-means and k-medoids  
182 clustering method) were performed to ensure the robustness of the results.  
183 Significance was set at  $p < 0.05$ . Analyses were performed using R<sup>®</sup> software version  
184 4.3.1.

## 185 **Ethics**

186 Department of data protection of the University of Lorraine confirmed that no identifying  
187 data were collected, therefore no consent was required. Data from the LimeSurvey  
188 questionnaire was only stored on our provider server (University of Lorraine server).  
189 Ethical approval was not required for this study according to the current French  
190 legislation.

## 191 **Results**

192

### 193 **Characteristics of students and faculties**

194 Among the 1,285 final-year students of dentistry registered during the 2022-2023  
195 academic year, 503 began the questionnaire and 415 students completed at least the  
196 topics (i) and (ii) and were included in this study (response rate: 32%). For one faculty,  
197 no student answered. The mean age of respondents was  $24 \pm 2$  years old, and 288  
198 (69%) were females.

199 Every faculty had a validation test at the end of the semester and had about  $39 \pm 14$   
200 hours of classes on microbiology with bacteriology and virology courses, infection  
201 prevention and control, antibiotic therapy, clinical cases and/or practical sessions of  
202 infectiology. Each faculty had different learning modalities. Among the 14 faculties  
203 responding, 3 (21%) had lecture courses only, 6 (43%) had practices, supervised  
204 learning and lecture courses, 2 (14%) had practices, supervised learning, lectures and  
205 case reports, 1 (7%) had lecture courses and e-learning, and 1 (7%) had all these  
206 modalities.

207 All these characteristics were then collected to explore potential associations with  
208 knowledge levels. The selected variables were included in the multivariate analysis to  
209 assess their impact on the knowledge scores.

### 210 **Students' level of knowledge**

211 The median knowledge score of students was 27/34 (IQR: 25-29). The detail of the  
212 response to each question included in the knowledge score is available in  
213 Supplementary data S1 (**table S1**). This table results indicate a generally good  
214 understanding of basic concepts such as antimicrobial resistance epidemiology, 391  
215 students (94%) were aware that France was one of the biggest antibiotic prescriber in

216 Europe and 329 (79%) considered the antibiotic resistance as a worldwide threat. In  
217 infectiology, gaps remain on specific topics like asymptomatic osteonecrosis: 187  
218 (45%) did not consider useful to prescribe antibiotics in this case, which was the good  
219 practical decision. Regarding antibiotic prescription recommendations, 132 (31%)  
220 students confirm awareness considering antibiotic prescription durations. Regarding  
221 clinical cases, 155 (37%) had the good medical approach in case of facial trauma.  
222 These findings highlight both strength and weaknesses in students' knowledge,  
223 particularly in applying theoretical knowledge to clinical scenarios.

#### 224 **Cluster analysis**

225 Two clusters were identified as the optimal number of clusters for our sample, using  
226 the elbow method. This method was applied by calculating the within-cluster sum of  
227 squares (WCSS) for a range of cluster numbers (from 1 to 10). A graph was plotted to  
228 visualize the results. The point of inflection on this graph, observed at  $k=2$ , indicated  
229 that two clusters were optimal to provide a simple model and to explain the variance.  
230 Additional analysis confirmed this choice by assessing the inertia relative to other  
231 cluster numbers (like  $k=3$ ). This analysis showed that using two clusters provided the  
232 most meaningful grouping of the data.

233 The cluster 1 "average level of knowledge" included 290 students (70%) with a median  
234 knowledge score of 26/34 (IQR: 24-27) with scores ranging from 8 to 27. The cluster  
235 2 "high level of knowledge" included 125 students (30%) with a median knowledge  
236 score of 30/34 (IQR: 29-32) with scores ranging from 27 to 34.

237 **Figure 1** (histogram of knowledge scores by cluster with ward clustering method)  
238 illustrates the knowledge score distribution across the clusters, revealing a minor  
239 overlap around the score 27. This overlap represents a natural transition zone between  
240 individuals with similar knowledge levels assigned to different clusters. This overlap

241 might not invalidate the robustness of the clustering solution, as the choice of two  
242 clusters is then confirmed through sensitivity analyses using other clustering methods.  
243 All of which identified two clusters as the most appropriate representation of the data.  
244 **Figure 2** (Histograms of the cluster-specific distributions of score) presents the  
245 distribution of scores for each cluster separately. The cluster “average level of  
246 knowledge” presents scores around the median range, with the majority of students  
247 scoring between 24 and 27. In contrast, the cluster “high level of knowledge” is  
248 characterized by a higher overall knowledge level.

249 **Table 1** presents the characteristics of students and faculties according to the two  
250 clusters. Most students were females (211, 73%) in the cluster “average level of  
251 knowledge”. Only 11 (4%) students in this cluster had mandatory courses. In the  
252 cluster “high level of knowledge”, 77 were female students (62%) and 14 students  
253 (11%) had mandatory courses.

254 Table 2 and 3 presents the factors analysed in the bivariate and multivariate models  
255 respectively, derived from the individual questionnaire responses. These factors were  
256 then associated with student’s knowledge scores.

257 **Table 2** shows that mandatory courses (OR 3.20, 95%IC 1.41-7.26,  $p=0.005$ ) and  
258 multiple learning modalities (OR 1.14, 95%IC 1.01-1.28,  $p=0.029$ ) were significantly  
259 associated with higher level of knowledge, along with gender (OR 1.66, 95%IC 1.06-  
260 2.56  $p=0.024$ ) and the mentor’s rural activity (OR 1.56, 95%IC 1.00-2.38,  $p=0.047$ ).

261 These significant variables were then included in the multivariate model, which  
262 achieved an AIC of 496,57. The final model identified three variables significantly  
263 associated with a high level of knowledge: mandatory courses (aOR 3.20, 95%IC 1.40-  
264 7.49,  $p=0.006$ ), multiple learning modalities (aOR 1.15, 95%IC 1.02-1.29,  $p=0.025$ ),  
265 and gender (aOR 1.72, 95%IC 1.08-2.70,  $p=0.021$ ), as shown in **table 3**.

266 Together, these results underline the importance of curricular design and pedagogical  
267 strategies in influencing knowledge acquisition.

### 268 **Sensitivity analyses**

269 We used two additional clustering methods, k-means and k-medoids, to validate  
270 results. Both methods produced close and coherent results, represented in the **tables**  
271 **S2 to S5**. The clustering process obtained the same distribution of students between  
272 clusters as observed with the main Ward method, supporting the consistency of the  
273 results. The gender variable had significant associations level in both univariate and  
274 multivariate analyses for all methods. Similarly, mandatory courses demonstrated high  
275 relevance in both sensitivity analyses. However, the “learning modalities” variable was  
276 excluded from the stepwise multivariable analysis in the k-means and k-medoids  
277 methods. This exclusion is linked to potential collinearity with “mandatory courses” in  
278 these clustering models. Despite this, the consistency of results across methods  
279 reinforces the robustness of the main findings regarding the importance of “mandatory  
280 courses” in high level of knowledge.

### 281 **Score gradient for learning modalities**

282 A score gradient has been identified descriptively, without formal statistical testing. The  
283 purpose was to associate the main knowledge score of each faculty with the proportion  
284 of mandatory courses offered, explaining an initial exploration of this potential  
285 relationship. There were 5 faculties that didn't have any mandatory courses, their  
286 median knowledge score was 26/34 (IQR: 24-27). Eight faculties had at least one  
287 mandatory course and reached a median knowledge score around 27/34 (IQR: 25-28).  
288 Finally, only one faculty offered a majority of mandatory courses, and obtained a  
289 median score of 29/34 (IQR:28-30). This finding supports the integration of mandatory

290 courses as potential strategy to improve students' academic and professional  
291 performances.

292

## 293 **Discussion**

294 This cross-sectional survey conducted among final-year French dental students  
295 highlighted that the global student's level of knowledge in infectiology and antibiotic  
296 stewardship was satisfying (median: 27/34). Some factors appeared associated with a  
297 high level of knowledge.

298 Having mandatory courses during the infectiology and microbiology training multiplies  
299 by 3.2 the chance to have a high level of knowledge. Other studies among the medical  
300 students showed that setting up mandatory courses, with interactive learning and  
301 practices improves knowledge and comfort levels towards encountering complicated  
302 and polypathological patients.<sup>24,25</sup> Students following mandatory courses were better  
303 prepared for clinical situations. This can illustrate the need to shift to standardized and  
304 mandatory courses in infectiology learnings.

305 Male students have a 1.72 higher chance of being in "the high level of knowledge" than  
306 female ones. This finding reveals a notable gender disparity. Similarly, a study  
307 conducted among French dentists showed male had better antibiotic prescription  
308 practices.<sup>26</sup>

309 The bivariate analysis highlighted a significant association between the multiple  
310 learning modalities and the level of knowledge. Among faculties which proposed  
311 different types of learning modalities like practices and supervised learning in addition  
312 to lectures, 27% of students had a high level of knowledge when 19% had an average  
313 level of knowledge. Wasson et al. had also showed that having additional learning  
314 modalities and not only lectures can increase the student's level, interest, and  
315 appropriateness in his use of antibiotics.<sup>24</sup> We can find this same result in an American  
316 study, which analysed the student's preference concerning different modalities of

317 learning infectiology. They needed standardized stewardship with practical and  
318 interactive learning experiences. That way, they could apply their skills and get  
319 feedbacks on their way to prescribe and communicate with the patient. They want to  
320 understand the rational reasons behind the recommendations, specifically to be able  
321 to argue and convince other health care professionals in the setting of conflict.<sup>25</sup>

322 However, this need of standardized and improved learning experiences must be  
323 understood in the specific context of French education. The fight against antibiotic  
324 resistance is a public health priority, as described in the 2022-2025 National Strategy  
325 for the Prevention of Infections and Antimicrobial Resistance in Human Health. The  
326 government emphasizes the importance of educating young practitioners. This study  
327 provides an opportunity to assess their knowledge, and the teaching methods used in  
328 France. In higher education, courses are rarely mandatory or interactive, which may  
329 limit the educational institution's ability to meet students' knowledge needs. Improving  
330 educational strategies is a key of the national infection prevention strategy. In France,  
331 there is a strong commitment to this strategy, reflected in the collective effort by  
332 faculties to enhance the training of young practitioners.

333 The French students had some difficulties regarding clinical cases and specifically  
334 handling a facial trauma (only 37% had the good approach). This could be explained  
335 by a lack of direct exposure to such cases during their training and insufficient  
336 confidence. For example, most students administer antibiotics after a trauma, possibly  
337 due to fear of complications or an unclear understanding of the severity of the situation,  
338 leading them to overprescribe antibiotics as a protective measure and for  
339 reassurance.<sup>12</sup> The same observation applies to the management of non-infected  
340 osteonecrosis: only 45% adhered to the recommendations and did not systematically  
341 prescribe antibiotic therapy. Osteonecrosis can be concerning for a dental student and

342 young dentist who is unfamiliar with these kinds of cases. Furthermore, an insufficient  
343 knowledge of the guidelines can cause these types of overprescription.

344 Nevertheless, they had good knowledge in epidemiology, infectiology generalities and  
345 antibiotic recommendations for the general population. But when it comes to patients  
346 with infectious risks, such as managing those at risk of infective endocarditis, students  
347 are more likely to prescribe antibiotics even when recommendations advise against it.  
348 Similarly, deficiencies in terms of dosage and choice of antimicrobial agents have been  
349 identified.

350 This analysis of infectiology education across dental schools highlights the variability  
351 in the number of teaching units, hours, and the scope of topics covered. The mission  
352 manager of each faculty described their educational programs towards one of the  
353 questionnaires. While some programs dedicate significant time to microbiology and  
354 hygiene, others adopted more diverse subjects such as antibiotic resistance, oral  
355 infections and therapeutic strategies. A few curricula stand out for integrating  
356 interdisciplinary seminars or innovative teaching methods. However, this heterogeneity  
357 suggests a need for more standardized and unified content and pedagogical  
358 approaches in infectiology education. Based on these observations, several key for  
359 improvement can be proposed for the harmonization of the core content. A majority of  
360 the faculties include essential topics such as general microbiology or hygiene, but there  
361 is a real need to include in all programs, some subjects that are not included in every  
362 faculty curriculum, like general and oral infectiology, prevention of infections and  
363 guidelines. Enhancing the focus on oral-specific infections and their management,  
364 which remain underdeveloped in certain curricula, is crucial.

365 This study presents a few limitations. Only 32% of the French final year students in  
366 dentistry were included in this study. Some similar publications had a participation rate

367 around 30% on a non-national level.<sup>24,25</sup> This low participation rate, combined with the  
368 exclusion of one faculty due to no responses, may have introduced selection bias,  
369 restricted the representativeness of the findings and reduced the statistical power to  
370 identify subtle differences. The participation was voluntary, this may be a source of  
371 self-selection bias. The students who answered the questionnaire might be more  
372 interested in antibiotic resistance and antibiotic stewardship than average. It may  
373 impact the generalizability of these findings to all French dental students. The sample  
374 might overrepresent individuals with a higher knowledge or motivation regarding these  
375 topics. Future studies could organize mandatory participation to ensure a more  
376 representative sample to the target population. Each student from 13 faculties  
377 answered directly by internet, one faculty conducted the questionnaire directly with the  
378 entire class, that represents 21% (87 students) of our population: 71% were grouped  
379 in the cluster "average level of knowledge", in line with the global result (70% of this  
380 study were grouped in the cluster "average level of knowledge"). The students  
381 answering at home have access to different resources. That might have artificially  
382 improved their knowledge score. However, knowing where to look and find the right  
383 information is also a guarantee of good practice.

384 Nevertheless, this study was to our knowledge the first study conducted on a national  
385 level, with 14 French faculties out of the 15 existing ones, with a participation rate  
386 comparable to other non-national studies evaluating the same subject.<sup>24,25</sup> Using a  
387 questionnaire developed by an expert group specifically for this study.

388 The present study shows that French students have good knowledge of antibiotics, yet  
389 the practitioners' prescriptions' quality is low.<sup>26</sup> This may be due to unconsciousness  
390 about antibiotic resistance despite proper training, or to a lack of up-to-date training of  
391 dentists in practice for many years. Even with infectiology education, students might

392 lack awareness about their role in antibiotic resistance. More than half of the students  
393 believe that dentists account for less than 10% of antibiotic prescriptions worldwide.  
394 This indicates a lack of awareness regarding the impact that dentists might have on  
395 antibiotic prescriptions and the development of antibiotic resistance.

396 This study highlights the necessity of implementing mandatory courses for better  
397 knowledge and improved patient care regarding infectiology and antibiotic  
398 stewardship. These mandatory courses should be developed with content specifically  
399 designed to address the current gaps in knowledge regarding these topics. The  
400 findings of this study also revealed disparities in the content of infectiology education  
401 across faculties, emphasizing the need of harmonisation. All these findings will be  
402 discussed and used by faculty representatives to identify leverage points for  
403 improvement. In terms of odontogenic infections, studies have underlined the  
404 importance of aligning educational programs with evidence-based guidelines to  
405 improve prescription habits and reduce the development of resistance<sup>4,6</sup>. This initiative  
406 could reduce disparities between students, improve their confidence, and enhance  
407 awareness, aligning with the French national strategy.

408 However, awareness about antibiotic resistance and the role of French and  
409 international dentists in the development of these resistances is crucial for enhancing  
410 prescription practices and education regarding antibiotic stewardship. Students and  
411 future practitioners must therefore strengthen their knowledge with a good sense of  
412 responsibility.

## 413 **Conclusion**

414 Dental students who had mandatory courses in their faculty had a high level of  
415 knowledge about antibiotic stewardship. The organization and various teaching

416 modalities are specific to each faculty. However, this study clearly demonstrates that  
417 certain teaching modalities are more effective than others, potentially serving as the  
418 foundation for adjustments in teaching methods. Future efforts should focus on  
419 harmonizing curricula while ensuring the quality of course content.

420 To work on these disparities, the establishment of a standardized, evidence-based  
421 national program is essential. This program should also integrate, in addition to  
422 mandatory courses, oral-specific infections and their management contents.

423 These measures have a large public health implication. Dental practitioners play an  
424 important role in combating antibiotic resistance through intelligent use of antibiotics  
425 and the prevention of healthcare-associated infections. By educating students with  
426 robust knowledge and skill, it may contribute to this global health challenge. Academic  
427 institutions must prioritize these reforms to align educational goals with the need to  
428 stop antibiotic resistance at both national and international levels.

#### 429 **Data Availability Statement**

430 Due to the nature of the research and ethical reasons, supporting data is not available.

431 **References**

- 432 1. WHO, World Health Organisation. WHO's first global report on antibiotic  
433 resistance: reveals serious worldwide threat to public health 2014.  
434 [https://www.who.int/southeastasia/news/detail/30-04-2014-who-s-first-global-](https://www.who.int/southeastasia/news/detail/30-04-2014-who-s-first-global-report-on-antibiotic-resistance-reveals-serious-worldwide-threat-to-public-health)  
435 [report-on-antibiotic-resistance-reveals-serious-worldwide-threat-to-public-](https://www.who.int/southeastasia/news/detail/30-04-2014-who-s-first-global-report-on-antibiotic-resistance-reveals-serious-worldwide-threat-to-public-health)  
436 [health](https://www.who.int/southeastasia/news/detail/30-04-2014-who-s-first-global-report-on-antibiotic-resistance-reveals-serious-worldwide-threat-to-public-health). Accessed November, 2022.
- 437 2. O'Neill J. Review on Antimicrobial Resistance. Tackling Drug-Resistant Infections  
438 Globally 2016 [https://amr-](https://amr-review.org/sites/default/files/160525_Final%20paper_with%20cover.pdf)  
439 [review.org/sites/default/files/160525\\_Final%20paper\\_with%20cover.pdf](https://amr-review.org/sites/default/files/160525_Final%20paper_with%20cover.pdf).  
440 Accessed August 23, 2023.
- 441 3. Contaldo M, D'Ambrosio F, Ferraro GA, *et al.* Antibiotics in Dentistry: A Narrative  
442 Review of the Evidence beyond the Myth. *Int J Environ Res Public Health*. 2023;  
443 20: 602.
- 444 4. Ardila CM, Bedoya-García JA. Antimicrobial resistance in patients with  
445 odontogenic infections: A systematic scoping review of prospective and  
446 experimental studies. *J Clin Exp Dent*. 2022 Oct 1;14(10):e834-e845.
- 447 5. Bahl R, Sandhu S, Singh K, Sahai N, Gupta M. Odontogenic infections:  
448 Microbiology and management. *Contemp Clin Dent*. 2014 Jul;5(3):307-11.
- 449 6. Swift JQ, Gulden WS. Antibiotic therapy--managing odontogenic infections. *Dent*  
450 *Clin North Am*. 2002 Oct;46(4):623-33, vii.
- 451 7. Cavalié P, Ben Hmidene G, Le Vu S, Maugat S, Berger-Carbonne A.  
452 Consommation d'antibiotiques en secteur de ville en France 2010 - 2020 Saint-  
453 Maurice : Santé publique France ; 2021.

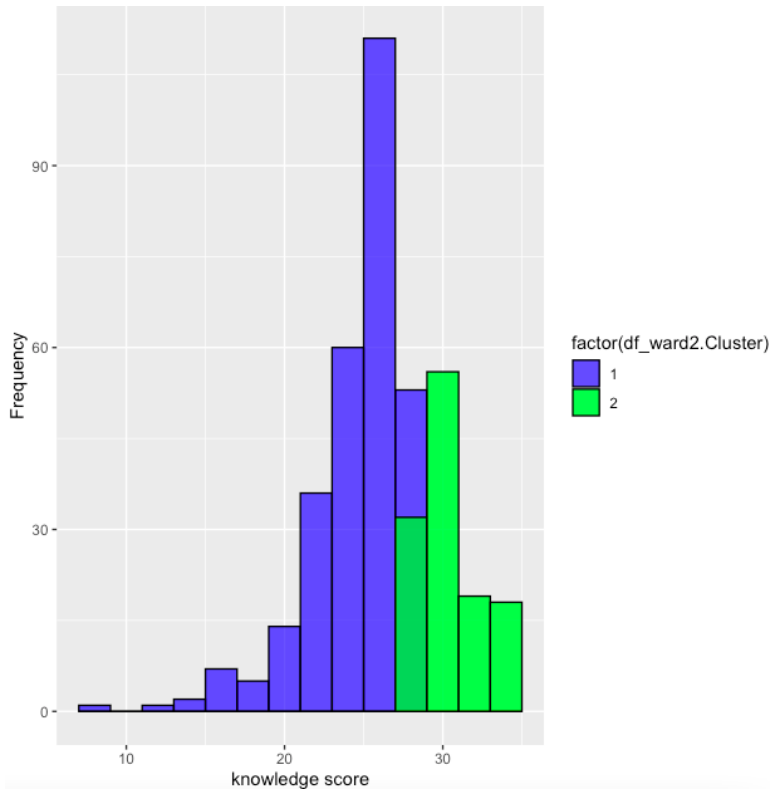
- 454 8. Preus HR, Fredriksen KW, Vogsland AE, Sandvik L, Grytten JI. Antibiotic-  
455 prescribing habits among Norwegian dentists: a survey over 25 years (1990-  
456 2015). *Eur J Oral Sci* 2017; 125: 280–287.
- 457 9. Cope AL, Francis NA, Wood F, Chestnutt IG. Antibiotic prescribing in UK general  
458 dental practice: a cross-sectional study. *Community Dent Oral Epidemiol* 2016;  
459 44: 145–153.
- 460 10. Mainjot A, D'Hoore W, Vanheusden A, Van Nieuwenhuysen J-P. Antibiotic  
461 prescribing in dental practice in Belgium. *Int Endod J* 2009; 42: 1112–1117.
- 462 11. Salvadori M, Audino E, Garo ML, Salgarello S. Antibiotic prescribing for  
463 endodontic infections: a survey of dental students in Italy. *Int Endod J* 2019; 52:  
464 1388-1396.
- 465 12. Dormoy J, Vuillemin M-O, Rossi S, Boivin J-M, Guillet J. Perceptions of antibiotic  
466 use and resistance: are antibiotics the dentists' anxiolytics? *Antibiotics (Basel)*.  
467 2021;10(6):735.
- 468 13. Baudet A, Kichenbrand C, Pulcini C, *et al.* Antibiotic use and resistance: a  
469 nationwide questionnaire survey among French dentists. *Eur J Clin Microbiol*  
470 *Infect Dis* 2020; 39: 1295-1303.
- 471 14. Phagava H, Balamtsarashvili T, Pagava K, Mchedlishvili I. Survey of practices,  
472 knowledge and attitude concerning antibiotics and antimicrobial resistance  
473 among medical university students. *Georgian Med News*. 2019; 294: 77-82.
- 474 15. Dyar O, Lund M, Lindsjo C, Stalsby Lundborg C, Pulcini C. Preparedness to  
475 prescribe antibiotics responsibly: a comparison between final year medical  
476 students in France and Sweden. *Eur J Clin Microbiol Infect Dis*. 2019; 38: 711-  
477 717.

- 478 16. Dyar O, Nathwani D, Monnet D, *et al.* Do medical students feel prepared to  
479 prescribe antibiotics responsibly? Results from a cross-sectional survey in 29  
480 European countries. *J Antimicrob Chemother.* 2018;73 8:2236-2242.
- 481 17. Ministère de la santé. Stratégie nationale 2022-2025 de prévention des infections  
482 et de l'antibiorésistance. Santé humaine 2022.  
483 [https://sante.gouv.fr/IMG/pdf/strategie\\_nationale\\_2022-](https://sante.gouv.fr/IMG/pdf/strategie_nationale_2022-2025_prevention_des_infections_et_de_l_antibioresistance.pdf)  
484 [2025\\_prevention\\_des\\_infections\\_et\\_de\\_l\\_antibioresistance.pdf](https://sante.gouv.fr/IMG/pdf/strategie_nationale_2022-2025_prevention_des_infections_et_de_l_antibioresistance.pdf). Accessed  
485 August 25, 2023.
- 486 18. SF2H, CMIT. Socle commun de compétences et connaissances minimales en  
487 prévention des infections et de l'antibiorésistance pour les professionnels de  
488 santé des filières maïeutique, médecine, odontologie, pharmacie, soins infirmiers  
489 2022. [https://www.sf2h.net/k-stock/data/uploads/2023/03/SocleCompetences-](https://www.sf2h.net/k-stock/data/uploads/2023/03/SocleCompetences-2022.pdf)  
490 [2022.pdf](https://www.sf2h.net/k-stock/data/uploads/2023/03/SocleCompetences-2022.pdf). Accessed August 25, 2023.
- 491 19. Akba A, Alquwez N, Alsolais A, Thazha S, Ahmad M, Cruz J. Knowledge about  
492 antibiotics and antibiotic resistance among health-related students in a Saudi  
493 University. *Infect Dev Ctries.* 2021;15(7): 925-933.
- 494 20. Holz M, Naavaal S, Stilianoudakis S, Carnico S, Byrne B, Myers G. Antibiotics  
495 and antimicrobial resistance: Evaluation of the knowledge, attitude, and  
496 perception among students and faculty within US dental schools. *J Dent Educ.*  
497 2021 Mar;85(3): 383-391.
- 498 21. Huang Y, Gu J, Zhang M, *et al.* Knowledge, attitude and practice of antibiotics: a  
499 questionnaire study among 2500 Chinese students. *BMC Med Educ.*  
500 2013;13:163.

- 501 22. Struzycka I, Mazinska B, Bachane T, *et al.* Knowledge of antibiotics and  
502 antimicrobial resistance amongst final year dental students of polish medical  
503 schools: a cross-sectional study. *Eur J Dent Educ.* 2019;23(3): 295-303.
- 504 23. ANSM. Prescription des antibiotiques en pratique buccodentaire.  
505 [Recommandations] 2011. [https://ansm.sante.fr/uploads/2021/02/04/reco-](https://ansm.sante.fr/uploads/2021/02/04/reco-prescription-des-antibiotiques-en-pratique-buccodentaire-septembre2011.pdf)  
506 [prescription-des-antibiotiques-en-pratique-buccodentaire-septembre2011.pdf.](https://ansm.sante.fr/uploads/2021/02/04/reco-prescription-des-antibiotiques-en-pratique-buccodentaire-septembre2011.pdf)  
507 Accessed August 25, 2023.
- 508 24. Wasson M, Luther V, Armstrong W, *et al.* Skills, not just knowledge: infectious  
509 diseases (ID) fellows' recommendations regarding antimicrobial stewardship  
510 training. *Clin Infect Dis.* 2023; ciad358.
- 511 25. Back D, Haberstroh N, Sostmann K, *et al.* High efficacy and students' satisfaction  
512 after voluntary vs mandatory use of an e-learning program in traumatology and  
513 orthopedics- a follow-up study. *J Surg Educ.* 2014;71(3): 353-9.
- 514  
515 26. Simon M, Pereira O, Constant ML, Guillet J, Pulcini C, Thilly N. Characteristics  
516 of dentists and patients associated with appropriate antibiotic prescriptions by  
517 French dentists: a cross-sectional study using Health Insurance databases. *BMC*  
518 *Oral Health.* 2023; 23(29).

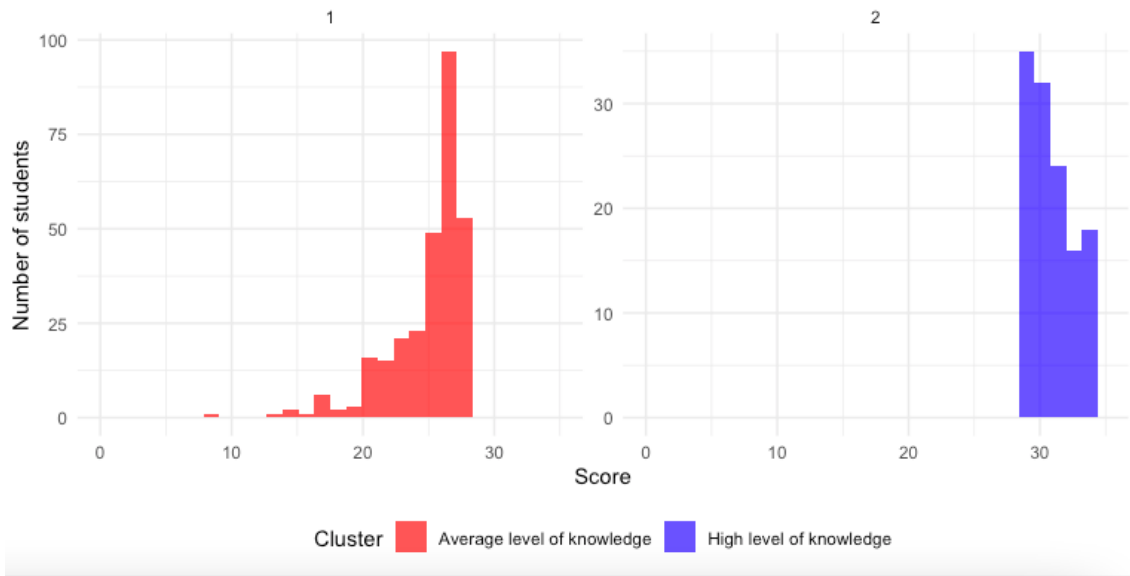
519  
520  
521

**Figure 1.** Histogram of knowledge scores by cluster with ward clustering method



522

**Figure 2.** Histograms of the cluster-specific distributions of score



524

525

526

527

528

**Table 1.** Population characteristics according to clusters from Ward method (N=415)

Characteristics		Total Population N = 415	Cluster 1 “Average level of knowledge” n = 290 (69.9%)	Cluster 2 “High level of knowledge” n = 125 (30.1%)
<b>Knowledge score (/34)</b>		27 (25-29)	26 (24-27)	30 (29-32)
<b>Student's age (years old)</b>		24 ± 2	24 ± 2	24 ± 2
<b>Student's gender</b>	Male	127 (31%)	79 (27%)	48 (38%)
	Female	288 (69%)	211 (73%)	77 (62%)
<b>Faculty</b>	F 1	29 (7%)	21 (7%)	8 (6%)
	F 2	72 (17%)	56 (19%)	16 (13%)
	F 3	27 (7%)	14 (5%)	13 (10%)
	F 4	11 (3%)	6 (2%)	5 (4%)
	F 5	13 (3%)	6 (2%)	7 (6%)
	F 6	19 (5%)	15 (5%)	4 (3%)
	F 7	11 (3%)	7 (2%)	4 (3%)
	F 8	35 (8%)	29 (10%)	6 (5%)
	F 9	4 (1%)	4 (1%)	0 (0%)
	F 10	20 (5%)	13 (4%)	7 (6%)
	F 11	9 (2%)	6 (3%)	3 (3%)
	F 12	NR	NR	NR
	F 13	87 (21%)	62 (21%)	25 (20%)
	F 14	25 (6%)	11 (4%)	14 (11%)
	F 15	53 (13%)	40 (14%)	13 (10%)
<b>Mandatory courses</b>		25 (6%)	11 (4%)	14 (11%)
<b>Additional non-mandatory courses</b>		400 (96%)	280 (97%)	120 (96%)
<b>Learning hours (hours)</b>		39 ± 13	39 ± 13	39 ± 8
<b>Multiple learning modalities</b>		149 (35%)	88 (30%)	61 (48%)
<b>Mentor's age</b>	Under 50 years old	137 (33%)	87 (30%)	50 (40%)
	Over 50 years old	278 (67%)	203 (70%)	75 (60%)
<b>Mentor's activity</b>	Rural	268 (65%)	192 (66%)	76 (61%)
	Urban	147 (35%)	98 (34%)	49 (39%)

531 **Table 2.** Comparison of student's and learning characteristics between the two clusters  
 532 (identified by the Ward clustering method) – Bivariate analyses (N = 415 students).  
 533

Characteristics		Cluster “High level of knowledge” versus Cluster “Average level of knowledge”	
		<i>Ref is average level of knowledge</i>	
		Odds Ratio (95% confidence interval)	p- value
<b>Student's age</b>		0.96 (0.87-1.07)	0.435
<b>Student's gender</b>	Female	1 (reference)	-
	Male	1.66 (1.06-2.56)	<b>0.024</b>
<b>Mentor's age</b>	Under 50 years old	1 (reference)	-
	Over 50 years old	1.26 (0.82-1.95)	0.291
<b>Mentor's activity</b>	Urban	1 (reference)	-
	Rural	1.56 (1.00-2.38)	<b>0.047</b>
<b>Mandatory courses</b>	None	1 (reference)	-
	At least one	3.20 (1.41-7.26)	<b>0.005</b>
<b>Additional non-mandatory courses</b>	None	1 (reference)	-
	At least one	0.86 (0.29-2.56)	0.782
<b>Learning hours</b>		1 (0.99-1.01)	0.586
<b>Multiple learning modalities</b>		1.14 (1.01-1.28)	<b>0.029</b>

534 Bold indicates a p-value < 0.10.

535 **Table 3.** Comparison of student’s and learning characteristics between the two  
 536 clusters (identified by the Ward clustering method) – Multivariable analyses (N = 415  
 537 students).

Characteristics		Cluster “High level of knowledge” versus Cluster “Average level of knowledge”	
		<i>Ref is cluster “average level of knowledge”</i>	
		Odds Ratio (95% confidence interval)	p- value
<b>Student’s gender</b>	Female	1 (reference)	-
	Male	1.72 (1.08- 2.70)	<b>0.021</b>
<b>Mentor’s activity</b>	Urban	1 (reference)	-
	Rural	1.53 (0.97 – 2.38)	0.064
<b>Mandatory courses</b>	None	1 (reference)	-
	At least one	3.20 (1.40 - 7.49)	<b>0.006</b>
<b>Multiple learning modalities</b>		1.15 (1.02-1.29)	<b>0.025</b>

538 Bold indicates a p-value < 0.05.

**Table S1:** 34-item questionnaire and results for each item (N=415)

<b>Items</b>	<b>Right answer</b>	<b>Number of students who responded well to this item (N=415)</b>
France is the country with the least use of antibiotics in Europe	False	391 (94%)
It is estimated that more than 5,500 deaths per year in France are attributable to antibiotic resistance.	True	352 (84%)
Less than 10% of antibiotics prescribed by French dentists are useless or inappropriate	False	332 (80%)
Less than 2500 patients develop each year in France an infection linked to a resistant bacterium according to a recent study	False	280 (67%)
Dentists are responsible for less than 10% of antibiotic prescriptions worldwide	False	228 (54%)
Antibiotic resistance is a source of a significant additional cost for health systems	True	376 (90%)
Someone can transmit an antibiotic-resistant bacterium to another individual, regardless of their state of health and even if the other one has never taken antibiotics in his life.	True	292 (70%)
Antibiotic resistance could, by 2050, become one of the main causes of death in the world	True	329 (79%)
Gram-positive bacteria are more present in the oral commensal flora of a healthy subject than Gram-negative bacteria.	True	279 (67%)
An antibiotic may be prescribed to treat a viral infection	False	362 (87%)
A focal oral infection is an infection localized to a distant organ, caused by an oral infectious focus	True	251 (78%)
A brain abscess can be caused by an oral infectious focus	True	325 (78%)
Spiramycine is an antibiotic	True	364 (60%)

<b>Osteonecrosis of the jaws requires antibiotic therapy, even in an asymptomatic situation</b>	False	187 (45%)
<b>Diclofenac is an antibiotic</b>	False	355 (85%)
<b>An anti-inflammatory must always be combined with antibiotic treatment</b>	False	354 (85%)
<b>Amoxicillin-clavulanic acid combines a penicillin with a beta-lactamase inhibitor</b>	True	311 (75%)
<b>The amoxicillin-clavulanic acid combination should never be prescribed as first-line therapy in dentistry</b>	False	194 (46%)
<b>Patients with moderate risk of infective endocarditis should be treated like the general population</b>	True	158 (38%)
<b>Patients with a heart murmur are at high risk for infective endocarditis</b>	False	354 (85%)
<b>An invasive act is an act that can lead to bacteremia and therefore likely to cause a local, distant, or even general infection.</b>	True	355 (85%)
<b>A patient with an orthopedic joint prosthesis requires antibiotic prophylaxis before any invasive oral procedure, to limit intraoperative bacteremia</b>	False	324 (78%)
<b>In the general population, antibiotic prophylaxis is indicated if you perform an avulsion requiring an alveolectomy</b>	False	296 (71%)
<b>In the general population, antibiotic prophylaxis is indicated in the event of avulsion of the mandibular third not impacted</b>	False	320 (77%)
<b>In the general population antibiotic prophylaxis is indicated for pre-implant surgery such as a sinus lift</b>	True	289 (70%)
<b>In the general population, all antibiotics used in dentistry are prescribed for a minimum of 7 days to treat a proven infection</b>	False	135 (32%)
<b>Concerning patients at high risk of infective endocarditis, antibiotic prophylaxis is not recommended for procedures involving manipulation of the gums such as scaling</b>	False	254 (61%)
<b>Concerning patients at high risk of infective endocarditis, antibiotic prophylaxis is indicated in the event of excision of a carious lesion remote from the dental pulp.</b>	False	257 (61%)
<b>Concerning patients at high risk of infective endocarditis, only an antibiotic</b>	True	246 (59%)

---

**prophylaxis is recommended to perform a simple dental extraction**

---

**Clinical case 1: Mr. A, 46 years old, comes to you, for pain regarding the tooth 42. The patient tells you that he was the victim of a public road accident 2 years ago, causing a displaced right parasymphiseal mandibular fracture, osteosynthesis, as you can see on the panoramic X-ray. He has no other history and is not taking any treatment. On clinical examination, you find the gums inflamed and note mobility of the tooth. Retro-alveolar X-ray reveals advanced root resorption of 42, indicating its avulsion.**

For this case, you do not prescribe antibiotics

311 (75%)

---

**Clinical case 2: Antoine, 7 years old, comes to the office because he fell from a bicycle 2 hours ago. The patient has no history but is allergic to penicillins. After cleaning with an antiseptic solution, you reduce the dislocation of 11, perform a bonded retainer, and:**

You only prescribe local treatments such as antiseptic mouthwashes to be carried out 3 times a day for 7 days.

155 (37%)

---

**Clinical case 3: Mr B, 21 years old, is referred to your practice for the removal of third molars. He weighs 80 kg, is in good general condition, has no medical history and has no allergies. He complains of severe radiating pain over 38. You clinically diagnose acute suppurative pericoronitis. You therefore plan to remove it as well as those of teeth 18 and 48 at the next appointment. What do you prescribe?**

You prescribe local care and 3 g of amoxicillin per day for 7 days, to start immediately to treat the pericoronitis, then 2 g to be taken 1 hour before the planned remote intervention.

217 (52%)

---

**Clinical case 4: You see Mrs. M in your office, she has an irreversible pulpitis of tooth 32. The patient has a mechanical mitral valve. The tooth can be preserved, and the canal light is clearly visible radiologically, so you decide to carry out the endodontic treatment, in a single session and under rubber dam. What do you prescribe?**

You prescribe 2 g of amoxicillin in one dose, one hour before performing the procedure.

248 (60%)

---

**Clinical case 5: A young 23-year-old patient presents for consultation. She has been complaining of major gingival pain (EN 8/10) for a week. She tells you that she is very stressed and smokes a lot.**

You prescribe metronidazole 1500 mg per day in 3 doses for 7 days.

233 (56%)

---

---

**You clinically diagnose necrotic ulcerative gingivitis. In addition to local care, what do you prescribe?**

---

541

542 **Table S2:** Comparison of student's and learning characteristics between the two clusters  
 543 (identified by the k-means clustering method) – Bivariate analyses (N = 415 students)  
 544

Characteristics		Cluster “High level of knowledge” versus Cluster “Average level of knowledge”	
		<i>Ref is average level of knowledge</i>	
		Odds Ratio (95% confidence interval)	p- value
<b>Student’s age</b>		0.90 (0.89-1.1)	0.864
<b>Student’s gender</b>	Male	1 (reference)	-
	Female	0.48 (0.27-0.84)	<b>0.010</b>
<b>Mentor’s age</b>	Under 50 years old	1 (reference)	-
	Over 50 years old	0.81 (0.51-1.31)	0.400
<b>Mentor’s activity</b>	Rural	1 (reference)	-
	Urban	1.04 (0.64-1.70)	<b>0.087</b>
<b>Mandatory courses</b>	None	1 (reference)	-
	At least one	2.17 (0.63-7.41)	<b>0.217</b>
<b>Additional non-mandatory courses</b>	None	1 (reference)	-
	At least one	0 (0-2-Inf)	0.980
<b>Learning hours</b>		1 (0.99-1.01)	0.360
<b>Multiple learning modalities</b>		1.21 (1.03-1.41)	<b>0.020</b>

545 Bold indicates a p-value < 0.10.

546 **Table S3:** Comparison of student's and learning characteristics between the two clusters  
 547 (identified by the k-medoids clustering method) – Bivariate analyses (N = 415 students)  
 548

Characteristics		Cluster “High level of knowledge” versus Cluster “Average level of knowledge”	
		<i>Ref is average level of knowledge</i>	
		Odds Ratio (95% confidence interval)	p- value
<b>Student's age</b>		0.94 (0.85-1.04)	0.219
<b>Student's gender</b>	Male	1 (reference)	-
	Female	0.62 (0.40-0.94)	<b>0.024</b>
<b>Mentor's age</b>	Under 50 years old	1 (reference)	-
	Over 50 years old	1.18 (0.79-1.78)	0.413
<b>Mentor's activity</b>	Rural	1 (reference)	-
	Urban	0.69 (0.46-1.05)	<b>0.082</b>
<b>Mandatory courses</b>	None	1 (reference)	-
	At least one	3.02 (1.27-7.17)	<b>0.012</b>
<b>Additional non-mandatory courses</b>	None	1 (reference)	-
	At least one	0.65 (0.23-1.82)	0.408
<b>Learning hours</b>		0.99 (0.99-1.00)	0.176
<b>Multiple learning modalities</b>		1.08 (0.97-1.21)	0.178

549 Bold indicates a p-value < 0.10.

550 **Table S4.** Comparison of student's and learning characteristics between the two  
 551 clusters (identified by the k-means clustering method) – Multivariable analyses (N =  
 552 415 students).

Characteristics		Cluster “High level of knowledge” versus Cluster “Average level of knowledge” <i>Ref is cluster “average level of knowledge”</i>	
		Odds Ratio (95% confidence interval)	p- value
<b>Student's gender</b>	Male	1 (reference)	-
	Female	0.43 (0.24- 0.76)	<b>0.004</b>
<b>Mentor's activity</b>	Rural	1 (reference)	-
	Urban	0.85 (0.48 – 1.51)	0.064
<b>Mandatory courses</b>	None	1 (reference)	-
	At least one	2.11 (1.10 – 4.25)	<b>0.029</b>

553 Bold indicates a p-value < 0.05.

554 **TableS5.** Comparison of student's and learning characteristics between the two  
 555 clusters (identified by the K-medoids clustering method) – Multivariable analyses (N =  
 556 415 students).

Characteristics		Cluster "High level of knowledge" versus Cluster "Average level of knowledge"	
		<i>Ref is cluster "average level of knowledge"</i>	
		Odds Ratio (95% confidence interval)	p- value
<b>Student's gender</b>	Male	1 (reference)	-
	Female	0.62 (0.4- 0.95)	<b>0.027</b>
<b>Mentor's activity</b>	Rural	1 (reference)	-
	Urban	0.67 (0.44 – 1.02)	0.064
<b>Mandatory courses</b>	None	1 (reference)	-
	At least one	2.83 (1.22 - 7.11)	<b>0.019</b>

557 Bold indicates a p-value < 0.05.