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# Is the implementation of the sixth-year clinical internship meeting the needs of dental students?

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## ABSTRACT

**Aims:** To assess the perceptions of the first two cohorts of students at the Faculty of Dental Medicine of Casablanca (2020/2021 and 2021/2022) regarding the implementation of the sixth year in their initial training curriculum.

**Methods:** This mixed-methods study combined qualitative and quantitative approaches. For the qualitative component, 20 participants from the first two cohorts were randomly selected and underwent semi-structured individual interviews. The data were analyzed using MAXQDA software. The quantitative study used a descriptive cross-sectional design and involved an online questionnaire administered to the second cohort (2021/2022). Data were processed using SPSS software.

**Results:** The response rate to the questionnaire was 92% (91/99). Most respondents (67.1%) reported being moderately to very satisfied with their sixth-year experience, and 92% felt better prepared for independent practice. However, only 49.5% of participants considered the intensive internship duration sufficient. While students generally acquired skills such as multidisciplinary treatment planning and surgical extractions, some skills, including immediate partial dentures (57%) and endodontic complication management (36.3%), required further development. Qualitative analysis revealed that 16 interviewees developed greater autonomy and self-confidence, while 10 participants found the clinical competency assessment exam comprehensive, although half experienced stress.

**Conclusion:** This study highlights students' perceptions of the sixth-year implementation and identifies areas for improvement, including clearer communication of objectives and enhancements to the intensive internship conditions. These recommendations should be considered to enhance the learning environment and training quality during the sixth year.

**Keywords:** Dentistry, curriculum, vocational training, clinical skills

## INTRODUCTION

In recent years, concerns have been raised by dentists regarding the level of competence of students nearing graduation and the quality of their training, particularly to ensure compliance with oral healthcare standards.[1] To address these challenges, several countries have implemented clinical learning internships, commonly referred to as "vocational training".[2] These internships vary widely between countries, taking place in either hospital or private practice environments, and may be mandatory or optional.[3-6]

Students at the Faculty of Dental Medicine in Casablanca, underwent a 5-year training program, with clinical rotations starting in the fourth year. However, students expressed concerns about the adequacy of this training for independent practice. A previous study conducted in 2015 among 115 fifth-year students during the 2014/2015 academic year investigated student perceptions of teaching methods. The study revealed that 50% of students lacked confidence in their ability to practice independently after graduation. Furthermore, half of the students believed that an additional year of clinical training would be beneficial.[7]

As part of a broader reform initiated in 2015, aimed at transforming the educational approach in dental medicine, the faculty introduced a sixth year of clinical training, focusing on holistic, patient-centered dental care. This addition aimed to enhance students' clinical expertise and prepare them for professional practice, ultimately better addressing the evolving needs of oral healthcare in Morocco.[8]

In accordance with Decree n°2176-18 of January 9, 2019,[9] the Ministry of Higher Education, in collaboration with Moroccan dental schools, implemented this clinical learning

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year, comprising two major internships: a multidisciplinary hospital internship and a professional immersion internship in private practice.

Assessing student perceptions on the new clinical sixth year was essential, given their stakeholder role and the absence of prior evaluations in Morocco.

Therefore, the present study aims to assess the satisfaction levels of the first two cohorts of students from the Casablanca Faculty of Dental Medicine affected by the reform in the 2020/2021 and 2021/2022 academic years regarding their internships. The study focuses on the attainment of educational objectives, the quality of supervision, and the evaluation methods. By examining the strengths and weaknesses of this new clinical sixth year, this study seeks to inform future refinements to the curriculum and enhance the overall quality of dental education in Morocco.

## METHODS

The study was carried out with the permission of the Hassan II University Ethics Committee (Date: 30.05.2025, Decision No: FMDC-pr2c/72-73-2023). All procedures were carried out in accordance with the ethical rules and the principles of the Declaration of Helsinki.

To meet our objectives, we used a mixed-methods approach, combining qualitative semi-structured interviews (conducted at participant-chosen locations) with a quantitative questionnaire-based study. Data collection and analysis took place over nine months.

The study population for the quantitative study consisted of all sixth-year students enrolled at the Casablanca Faculty of Dental Medicine during the 2021-2022 academic year, with the exception of those repeating their year. The first cohort of 2020/2021 was excluded from the quantitative study due to the disruption caused by the COVID-19 pandemic, which resulted in reduced clinical activities and a delayed start of nearly two and a half months.

Participants were required to have completed both internship periods and their clinical skills examinations (CSE). For the qualitative study, a sample of 20 participants was randomly selected, consisting of 10 graduates from the 2020-2021 cohort and 10 students from the 2021-2022 cohort.

Informed consent was obtained from each participant via written consent forms that clearly outlined the purpose of the study and the participants' rights. Following permission from the faculty's administrative department to access the complete lists, an online questionnaire was distributed using Google Forms through the WhatsApp platform. The questionnaire contained 34 questions, including 27 closed-ended and 7 open-ended questions, organized into four sections relating to participant identification, perceptions of the multidisciplinary clinical internship (the skills being evaluated align with those outlined for the European dentist by the DentEd Network[10]), perceptions of the professional immersion internship and perceptions of evaluation procedures. Data entry was performed using SPSS software

For the qualitative study, an interview guide was used. The questions were structured according to the hourglass technique, progressing from more general to more specific inquiries. Before starting the interview, participants signed a consent form regarding the audio recording of the interview. Individual interviews were conducted face-to-face, and recordings were made using the « voice memo » application on the investigator's smartphone. Respect for anonymity and confidentiality was communicated from the outset.

The interviews were semi-structured, allowing participants to freely express their views on specific pre-prepared questions while enabling interviewers to encourage deeper exploration of the topics. The first pilot interview and three others were excluded due to insufficiently relevant data. Each interview lasted between 20 minutes and 1 hour.

### Statistical Analysis

Data analysis was conducted using MAXQDA software (Berlin, Germany).[11] The interviews were transcribed verbatim, then segmented to identify key themes.[12] After verbatim transcription, the data were segmented to identify key themes, coded, and synthesized into a thematic grid based on the initial interview guide. The results were given as percentages.

## RESULTS

Of the 99 students invited to participate, 91 responded to the online questionnaire, resulting in a response rate of 92%. The respondent sample consisted of 62.6% female students, with a mean age of 24 years (SD=1 year). For the qualitative study, initially, a random sample of 20 participants was selected. The pilot interview was excluded from the analysis, and three additional interviews were excluded due to insufficient relevance of the collected data. Therefore, 20 out of 24 conducted interviews were deemed suitable for analysis and were included in our study.

### Students' Perceptions of the Multidisciplinary Clinical Internship Experience in the University-Hospital Dental Center

Overall, 67.1% of respondents expressed moderate to very high satisfaction with their internship experience. The qualitative study revealed that both cohorts held a overwhelmingly positive view of the introduction of the sixth year, with participants commenting, "we learned a great deal" and "the sixth year was a valuable addition for us."

Students generally reported acquiring competencies in various areas, including planning multidisciplinary treatment projects, performing surgical extractions, managing pediatric patients, and creating supragingival prostheses. **Table 1** summarizes students' self-assessed competencies. Notably, participants expressed limited confidence in their ability to perform immediate removable prostheses (57.1%), conduct simple periodontal surgical interventions (51.6%), manage medically compromised pediatric patients (38,5%) and manage periodontal emergencies (37.4%).

Further development is needed in competencies such as managing endodontic complications (36%) and addressing endodontic failures (33%) and developing skills like communication, organization, and ergonomics (10%). The qualitative study revealed that students perceived gaps in their training, particularly in fixed prosthodontics (13 respondents), cone beam computed tomography interpretation (10), oral surgery (10 respondents) and molar endodontics.[8]

Opinions on the Functional Rehabilitation of Dental Arches (RFA) module, a new internship combining restorative and

**Table 1 . Competencies perceived as acquired during the multidisciplinary internship**

| According to you, what competencies do you believe you have acquired during the multidisciplinary internship | Acquired | Moderately acquired | Not acquired | I don't know |
|---|---|---|---|---|
| Plan a multidisciplinary treatment project for a partially edentulous patient | 60 (65.9%) | 31 (34.1%) | - | - |
| Deduce and prioritize therapeutic goals for a functional rehabilitation of the arches | 55 (60.4%) | 35 (38.5%) | 1 (1.1%) | - |
| Be autonomous during a prosthetic rehabilitation with a composite prosthesis | 32 (35.2%) | 42 (46.2%) | 15 (16.5%) | 2 (2.2%) |
| Perform an immediate removable prosthesis | 12 (13.2%) | 24 (26.4%) | 52 (57.1%) | 3 (3.3%) |
| Perform a supragingival prosthesis | 37 (40.7%) | 31 (34.1%) | 19 (20.9%) | 4 (4.4%) |
| Be capable of performing complex acts in endodontics (stratification, endodontic retreatment) | 35 (38.5%) | 44 (48.4%) | 11 (12.1%) | 1 (1.1%) |
| Be capable of managing endodontic complications | 18 (19.8%) | 39 (42.9%) | 33 (36.3%) | 1 (1.1%) |
| Manage at-risk children | 24 (26.4%) | 30 (33%) | 35 (38.5%) | 2 (2.2%) |
| Manage children with early childhood caries | 49 (53.8%) | 27 (29.7%) | 15 (16.5%) | - |
| Follow up on dental trauma in pediatric dentistry | 27 (29.7%) | 39 (42.9%) | 23 (25.3%) | 2 (2.2%) |
| Manage difficult child behavior | 27 (2.7%) | 54 (59.3%) | 9 (9.9%) | 1 (1.1%) |
| Perform simple surgical interventions in periodontology | 17 (18.7%) | 23 (25.3%) | 47 (51.6%) | 4 (4.4%) |
| Performing surgical extractions | 51 (56%) | 32 (35.2%) | 8 (8.8%) | - |
| Being autonomous during the care of at-risk patients | 50 (54.9%) | 33 (36.3%) | 6 (6.6%) | 2 (2.2%) |
| Managing complications during dental extraction | 34 (37.4%) | 39 (42.9%) | 15 (16.5%) | 3 (3.3%) |
| Being capable of managing dental emergencies | 36 (39.6%) | 45 (49.5%) | 8 (8.8%) | 2 (2.2%) |
| Being capable of managing periodontal emergencies: | 13 (14.3%) | 41 (45.1%) | 34 (37.4%) | 3 (3.3%) |
| Managing a traumatized patient | 17 (18.7%) | 49 (53.8%) | 23 (25.3%) | 2 (2.2%) |
| Proposing an orthodontic treatment plan and its multidisciplinary implications | 19 (20.9%) | 44 (48.4%) | 22 (2.2%) | 6 (6.6%) |
| Performing preventive and interceptive treatment considering multidisciplinary approaches | 32 (35.2%) | 39 (42.9%) | 18 (19.8%) | 2 (2.2%) |
| Interpreting a panoramic radiograph | 72 (79.1%) | 16 (17.6%) | 2 (2.2%) | 1 (1.1%) |
| Interpreting a cone-beam | 17 (18.7%) | 50 (54.9%) | 22 (2.2%) | 2 (2.2%) |
| Mastering practical radiation protection rules | 40 (44%) | 28 (30.8%) | 22 (24.2%) | 1 (1.1%) |

endodontic dentistry, fixed and removable prosthodontics, were mixed. While the cohorts appreciated its introduction, citing comprehensive patient care and personal fulfillment, patient recruitment posed a significant challenge (87.9%), primarily due to financial constraints (65.9%).

Regarding the clinical supervision provided by instructors, our students reported receiving constructive and supportive feedback from instructors, particularly in the departments of surgical dentistry (72.5%), conservative dentistry (52.7%), and orthodontics and dentofacial orthopedics (50.5%).

The qualitative study revealed mixed opinions. However, half of the participants reported a positive experience with a significant improvement compared to their experiences in the 4$^{th}$ and 5$^{th}$ years. They felt that this enhanced supervision promoted autonomy and confidence in delivering dental care. "We're given more freedom and treated as colleagues without authority" (2021-2022 cohort).

## Students' Perceptions of the Immersion Internship in Private Dental Practices

Overall, 86.8% of students reported feeling well-treated and respected during their training. In the qualitative study, 16 participants described a positive working relationship with their internship supervisor, citing effective communication and discussions about clinical cases.

**Table 2** summarizes students' perceptions of the competencies acquired during the immersion internship. Additional skills identified by respondents included developing strategies to enhance clinical practice, familiarizing themselves with new materials and equipment, gaining exposure to complex surgical procedures, improving patient-practitioner relationship management, and gaining insights into dental practice management and teamwork. The importance of developing autonomy, efficiency, and speed was also emphasized.

## Perception of Assessment Methods

71.4% of students felt that the assessment methods accurately reflected their performance.

In terms of clinical case presentations, 47.3% of students rated the organization as good, while 45.1% considered it average.

**Table 3** summarizes the key aspects of students' perceptions of the assessment methods.

8 out of 19 students expressed strong opposition to the quota-based validation system, citing concerns over heightened

**Table 2. Competencies perceived as acquired during the immersion internship**

| Variables | Strongly agree, n (%) | Moderately agree, n (%) | Disagree, n (%) | I don't know, n (%) |
|---|---|---|---|---|
| Relationship management with the healthcare team | 52 (57.1%) | 30 (33.0%) | 9 (9.9%) | - |
| Relationship management with the patient | 56 (61.5%) | 29 (31.9%) | 5 (5.5%) | 1 (1.1%) |
| Financial management of the practice | 17 (18.7%) | 34 (37.4%) | 39 (42.9%) | 1 (1.1%) |
| Hygiene and asepsis | 61(67%) | 20 (22%) | 9 (9.9%) | 1(1.1%) |

**Table 3. Perception of assessment methods by students**

| Variables | Yes, n (%) | No, n (%) |
|---|---|---|
| In your opinion, do the assessment methods used for each service reflect your actual level of performance? | 65 (71.4%) | 26 (28.6%) |
| Was the management of the multidisciplinary case completed? | 56 (61.5%) | 35 (38.5%) |
| Does the clinical examination for competency assessment reliably evaluate synthesis and clinical analysis skills? | 49 (53.8%) | 42 (46.2%) |

stress levels, compromised patient care quality, and hindered clinical learning. Typical comments included: "I didn't expect to have a quota system in my 6th year" and "Quota are a bad idea... It stress me out and undermine my learning experience."

Both cohorts of students reported experiencing delays in communication about assessment methods for each service, except for functional rehabilitation of arches. Twelve interviewees praised the format of the clinical examination for competency assessment, citing its thorough review, opportunities for direct interaction with jury members, promotion of reflective practice, and confidence-building effects. However, some respondents expressed concerns that the examination was overly influenced by jury preferences and that preparation was hindered by the absence of a syllabus and review courses.

## DISCUSSION

Our study is part of a quality improvement initiative and provides the first evidence of the effectiveness of the dental education reform implemented in Morocco in 2015. This research represents the first of its kind conducted at a dental school in Casablanca, aiming to comprehensively examine various aspects of clinical internships and their evaluation methods.

We used a mixed-methods design, known as a convergent research design, which integrates qualitative and quantitative approaches. In this design, qualitative and quantitative data are collected and analyzed separately before being compared.[11] This method provides a more comprehensive understanding of the phenomenon under study, as the strengths of one approach can offset the limitations of the other.

The results are representative of the studied population, with 92% of sixth-year students from the 2021/2022 cohort responding to the questionnaire. Sixty-seven percent of students expressed moderate to satisfactory satisfaction levels regarding the addition of the sixth year, which is reflected in the qualitative study. Furthermore, 92% of students felt better prepared for independent practice. This finding aligns with a study conducted at the dental school in Nancy, where 78% of students who completed their final internship felt adequately prepared to enter their professional lives under favorable conditions.[4]

In contrast, a survey conducted at the dental school in Monastir (Tunisia) in 2021 indicated that over half of the sixth-year interns (54.6%) believed that their prior clinical training did not adequately prepare them for independent practice, with suggestions including the addition of a seventh year dedicated exclusively to clinical learning.[5]

Half of the students from the 2021/2022 cohort believed that the 20-week duration was adequate to achieve the internship objectives, provided that patient recruitment started early. This was especially important for functional rehabilitation of arches, which requires multidisciplinary care across three different services.

Regarding clinical supervision, half of the students in the same cohort felt that it offered constructive and supportive feedback in all services. This perspective was confirmed in interviews, where students expressed that this supervision granted them more freedom and autonomy, ultimately boosting their confidence in delivering dental care. According to Harley, the level of support from a supervisor should be inversely proportional to the students' experience; as students develop their skills, the supervisor's interventions should diminish.[6] To further enrich students' clinical learning, encouraging self-reflection and providing regular constructive feedback are recommended.[13,14]

The implementation of the functional rehabilitation of arches internship was positively received by the entire 2020-2021 cohort. However, the program faced challenges, particularly in patient recruitment. In fact, 88% of students reported difficulties in locating patients who needed multidisciplinary care. These findings are consistent with a study conducted in the United States, where students similarly expressed concerns about laboratory issues and administrative paperwork complicating patient recruitment.[15]

All respondents indicated that they had acquired the fundamental aspects of clinical practice (simple procedures), with varying levels of mastery. Skills such as planning a multidisciplinary project, managing early childhood caries, and performing surgical extractions were among those perceived as acquired. However, 13 out of 20 respondents felt they still had gaps in fixed prosthodontics, while 8 out of 20 identified deficiencies in endodontics. which is concerning given the community's significant need for root canal treatments on molars and fixed prostheses.

Despite basic training and internships, several studies have highlighted persistent gaps in dental students' skills, particularly in areas such as molar endodontics, fixed prosthodontics, and orthodontics. For instance, a study conducted at three dental institutions in Pakistan found that while 134 students felt adequately prepared for clinical procedures like fillings and tooth extractions, they reported low preparedness for more complex tasks, including intraoral radiographs, treatment planning, and multirooted endodontics.[16] Similarly, a study among final-year dental students and interns at three Saudi dental institutions revealed that participants lacked confidence in performing procedures like multirooted endodontics, removable dentures fabrication and orthodontic assessments.[17]

Youngson et al.[18] reported that a significant number of dental schools do not expect their students to have completed a substantial number of cases involving bridges or endodontic procedures, suggesting that poorly acquired skills can be addressed later through field experience.

Macluskey et al.[19] attributed the lack of confidence in performing procedures to limited experience and insufficient supervision highlighting the need for adequate training and guidance to develop these skills.

Although students have developed skills, they reported average satisfaction with the implementation and relevance of services, citing limitations such as restricted patient accessibility, stringent validation criteria, and outdated infrastructure and technology compared to private dental clinics. In response to the growing number of students, the Faculty of Dental Medicine of Casablanca has expanded its teaching team to ensure adequate supervision during multidisciplinary clinical internships, providing hands-on experience with real patients. In contrast, several dental institutions have struggled to provide sufficient clinical experience due to rising enrollment and a shortage of available patients. As a result, these institutions have increasingly adopted educational approaches that rely on digital dentistry and simulators, as seen in UK and Ireland dental schools. While supervisors are satisfied with trainees' preparation in areas like health promotion and basic clinical procedures, they express concerns about proficiency in critical areas such as treatment planning, removable prosthetics, and endodontics (multi-rooted cases), surgical extractions, and the placement of crowns and bridges.[20]

It is important to note that competence and the perception of competence (confidence) are distinct concepts. A student may either overestimate their abilities or, conversely, lack confidence in their capacity to perform specific procedures.[5] Therefore, it is crucial to approach data regarding students' perceptions of their acquired competencies with caution, as they may be unwilling to admit a lack of confidence in skills deemed essential for independent practice, or the opposite may be true.

The implementation of the active professional immersion internship aligns with the institution's objectives and the students' desire to reinforce their knowledge and address identified gaps. This initiative fosters an awareness of independent practice demands and enables controlled autonomy in patient care.[21,22] As students possess sufficient maturity, they can appreciate the care provided and focus on office management, regulations, sterilization, accounting and various paraclinical aspects.

The faculty of dental medicine has established a list of approved dentists to supervise internships, based on a specific agreement with the National Order of Dentists. Internship validation relies on a standardized evaluation grid, completed by the supervisor, and a student self-assessment grid, both stored in a student-held notebook. Although widely adopted, this approach poses a risk of fraud due to student possession of the notebook.[23]

Our study showed high student satisfaction with their internship experience, with 64% very satisfied and 70% finding the 10-week duration adequate. This is consistent with a University of Bordeaux study, where 95% of students rated their internship highly (average score: 7.8/10).[24] Through their private healthcare internship, students acquired skills in patient management, technical platform discovery, complex surgery initiation, financial management, accounting, and treatment planning.

Several European countries, including France, Germany, Switzerland, Denmark, Poland, Finland, the UK, and Ireland, have incorporated vocational training into their educational curricula. The literature unanimously agrees on its beneficial effects but reports significant heterogeneity in the organization of these internships across Europe. The duration of these internships varies by country, ranging from one year in the UK, Denmark, and Poland, to two years in Germany. In the UK, this internship is an integral part of the curriculum, organized at the end of studies, after graduation, and before registration with the General Dental Council.[25] In Germany, the internship takes place after graduation, and students must complete a two-year full-time practical internship to obtain authorization from social security organizations to treat private sector patients.[26]

With regard to assessment methods, half of the respondents were opposed to validation based on a quota system, citing concerns that it could generate stress and compromise patient care quality. These findings are consistent with a 2017 study on evaluation methods among 4th and 5th year students of the Faculty of Dental medicine of Casablanca, which reported a primary focus on procedure-based evaluation.[27] A New Zealand study recommended abolishing the quota-based validation system, advocating instead for a focus on the quality of task execution.[28]

At the end of the multidisciplinary deepening internship, students are expected to present a 10-minute overview of their functional rehabilitation of the arches therapeutic project, during which they are evaluated on the relevance of their diagnostic and therapeutic approach. Nineteen respondents appreciated this process, stating that it validated their overall work while simultaneously assessing their theoretical knowledge and its application in clinical cases. According to a study conducted at Harvard Dental School, students valued the opportunity to engage in constructive discussions about their strengths and weaknesses during presentations involving multidisciplinary care.[29]

## Recommendations

To optimize clinical learning in the 6th year and improve the effectiveness of student's internships, we recommend the following measures;

**Multidisciplinary deepening internship:**

- Increase the duration of the internship.
- Adjust scheduling slots for better organization.
- Improve the clinical environment and modernize the technical equipment at the Dental Consultation and Treatment Center of Casablanca.
- Clearly communicate and adhere to the previously announced internship objectives.
- Schedule regular staff meetings to discuss clinical cases.

**Professional immersion internship:**

- Clearly communicate the objectives to supervisors to enable them to effectively support the students.
- Provide supervisors with training that includes a pedagogical component.
- Establish a structured timeline for the internship that includes an initial observation phase, followed by a semi-autonomous patient care phase, and concluding with a fully autonomous practice phase.

- Consider introducing a mandatory observation internship at the end of the fifth year to reduce the duration of the observation phase during the professional immersion internship.

**Evaluation methods:**

- Reassess validation criteria to eliminate the quota-based system and instead emphasize the recognition of individual effort.
- Enhance preparation for the habilitation exam by scheduling revision sessions in advance and providing a list of courses to review, thereby reducing stress.
- Allocate additional reflection time during the arch's functional rehabilitation exam.

### Limitations

Although the results of this study are relevant, they are based solely on self-reported data and may lack generalizability to other contexts. A multi-center study conducted in collaboration with the Rabat Dental Public Faculty, with which we share similarities in characteristics of enrolled students, curriculum and teaching methods and other private dental schools would be highly beneficial. To enhance objectivity in this initial impact study, comparing students' perceptions with those of teachers and supervisors would be insightful. Furthermore, a correlation study examining the relationship between perceived skills acquisition and clinical placement results, assessments, and grades would be relevant.

## CONCLUSION

This study reveals that sixth-year students exhibit high overall satisfaction with their progress, driven primarily by comprehensive patient care experiences, acquisition of novel skills across various disciplines, and reinforcement of existing competencies. These key elements collectively foster enhanced self-esteem and autonomy, empowering students to transition confidently into professional practice.

## ETHICAL DECLARATIONS

### Ethics Committee Approval

The study was carried out with the permission of the Hassan II University Ethics Committee (Date: 30.05.2025, Decision No: FMDC-pr2c/72-73-2023).

### Informed Consent

Informed consent was obtained from each participant via written consent forms that clearly outlined the purpose of the study and the participants' rights.

### Referee Evaluation Process

Externally peer-reviewed.

### Conflict of Interest Statement

The authors have no conflicts of interest to declare.

### Financial Disclosure

The authors declared that this study has received no financial support.

### Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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# Finite element analysis of stress distribution in implant, abutment, screw and bone using different superstructure materials in implant-retained fixed partial dentures

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## ABSTRACT

**Aims:** Aim of this study is to evaluate the stresses of the implant and implant surrounding tissues by using different superstructure materials by using the finite element method.

**Methods:** In our study, titanium implants with a diameter of 3.3 mm and 4.8 mm were placed in the 2nd premolar and 2nd molar region of mandibula, respectively. Bone modeling was performed in order to analyse stress distribution by finite element method. 4 different 3-member bridge prostheses were designed by using porcelain fused metal, monolithic zirconia, porcelain fused zirconia and PEEK substructures on the titanium abutments. Analyzes were performed by vertical and oblique forces applied to the occlusal surface.

**Results:** Oblique forces were found more destructive than vertical forces in all study groups. Stresses depending on the effect of the forces in the bone were affected by compression forces in 4 groups. Stresses in implant, abutment and screw were found around neck area. Stresses in crown were found around connector and margin areas.

**Conclusion:** It is concluded that the stresses that occur as a result of the applied forces occur at least in zirconia generally.

**Keywords:** PEEK, monolithic zirconia, zirconia, finite element analysis, dental implant

## INTRODUCTION

Throughout history, teeth have symbolized youth, prestige, aesthetics, and health. Consequently, tooth loss has not only resulted in functional impairments but also psychological and social challenges, contributing to the advancement of modern dentistry.[1]

Dental implants have become a crucial treatment modality for the replacement of missing teeth. Ongoing research continues to explore optimal implant designs, surface characteristics, load distribution, and appropriate restorative materials to enhance clinical success.[2]

Unlike natural teeth, dental implants lack a periodontal ligament and transmit occlusal forces directly to the alveolar bone.[3] Proper load distribution is critical for implant longevity, as excessive or misdirected forces may lead to marginal bone loss or prosthetic complications.[4-6]

Factors such as the magnitude and direction of occlusal forces, the restorative design, superstructure material, implant design and number, and bone quality significantly influence load transmission and implant longevity.[7-9] Improper force distribution can result in marginal bone resorption and eventual implant failure.[8] Therefore, selecting the most appropriate prosthetic design and material is essential for long-term success.[10,11]

Finite element analysis (FEA) has been widely used in implant dentistry since 1976 to assess biomechanical behavior under various loading conditions.[11,12] Han et al.,[5] and Almeida et al.[6] recently applied 3D FEA to evaluate stress distribution in implants with different superstructure materials, confirming its reliability for simulating clinical scenarios. FEA enables realistic simulations of clinical scenarios by modeling bone, implant, and prosthetic components, allowing for accurate stress localization analysis that is otherwise difficult to measure in vivo.[13,14] With the FEA procedure, bone, implant and over-implant structures can be modeled close to clinical conditions. Thus, with the applied forces, it makes it possible to accurately monitor the localization of stress and bone losses occurring in the implant and surrounding bone.[15-19]

Although metal-ceramic restorations remain the gold standard due to their strength and long-term clinical performance, concerns regarding metal allergies and esthetic limitations have led to the increased use of metal-free alternatives such as zirconia and PEEK.[20] Monolithic zirconia and PEEK offer improved aesthetics, biocompability and stress distibution compared to metal-ceramic restorations.[4,21] Recent developments in monolithic materials aim to overcome veneering ceramic chipping and improve mechanical performance.[20]

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This study aims to evaluate the stress distribution in implants, abutments, screws, and surrounding bone under vertical and oblique loading using various superstructure materials including porcelain fused metal (PFM), monolithic zirconia, porcelain-fused-zirconia, and PEEK through three-dimensional FEA analysis.

## METHODS

This study did not require ethical approval as it did not involve any human subjects or animal experiments. All procedures were carried out in accordance with the ethical rules and the principles.

This finite element analysis was conducted in collaboration with Dicle University, Faculty of Dentistry and Ay Tasarım Ltd. Co. The analysis and modeling were performed using the following hardware and software:

- Intel Xeon® R CPU @ 3.30 GHz, 14 GB RAM, Windows 7 Ultimate
- +Optical scanner: Activity 880 (Smart Optics, Germany)
- 3D modeling: Rhinoceros 4.0 (Seattle, WA, USA)
- Mesh generation: VRMesh Studio (VirtualGrid Inc., Bellevue, WA, USA)
- Finite element analysis: Algor Fempro (ALGOR Inc., Pittsburgh, PA, USA)

After the geometrical models were created using VRMesh software, they were exported in STL format and transferred to the Algor Fempro software for analysis and preparation. The STL format is a universal format for 3D modeling programs and stores the coordinate information of nodes, preventing data loss during inter-program transfers. Material properties (elastic modulus and Poisson's ratio) were assigned to each structural component in the model. The bridge restoration model was digitally designed to match anatomical tooth dimensions as defined in Wheeler's anatomy atlas.

### Preparation of Models

In this study, four different models were created. All models used titanium implants and abutments, but differed in prosthetic superstructure materials (Metal supported porcelain, Monolithic Zirconia, Zirconia based porcelain, PEEK).

**Modeling of mandibular cortical bone:** Using Rhinoceros software, a 20x20x2 mm cortical bone block was first modeled. The periodontal ligament (PDL) space was subtracted using the Boolean method to enable implant and cortical bone alignment. A 0.2 mm thick lamina dura was also modeled (**Figure 1**).

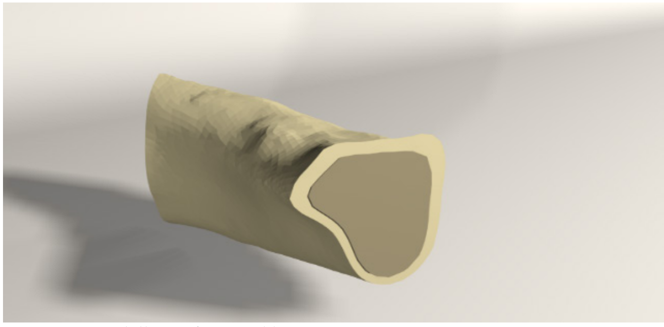

**Figure 1.** Modelling of cortical bone

Boundary conditions were set by fixing the lower and lateral surfaces of the bone model at 0 degrees of freedom (DOF) (**Figure 2**).

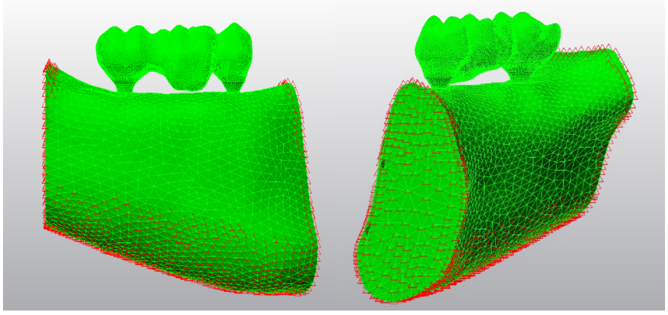

**Figure 2.** Boundary conditions applied to the models

**Modeling of implants, abutments and screws:** Implants were positioned at the sites of the second premolars and second molars, guided by anatomical landmarks. The vertical line passing through the mental foramen was accepted as the mesial border of the second premolars. The distal margin was anatomically determined using measurements from Wheeler's atlas.[15]

Titanium implants (Bone Level, Straumann, Basel, Switzerland) with a standard diameter of 3.3 mm and length of 10 mm were placed in the second premolars, while wider implants with a 4.8 mm diameter and the same length were used for the second molars. Titanium abutments (Straumann NC and RC Cementable Abutments) with a 3.5 mm emergence profile were used (**Figure 3-5**).

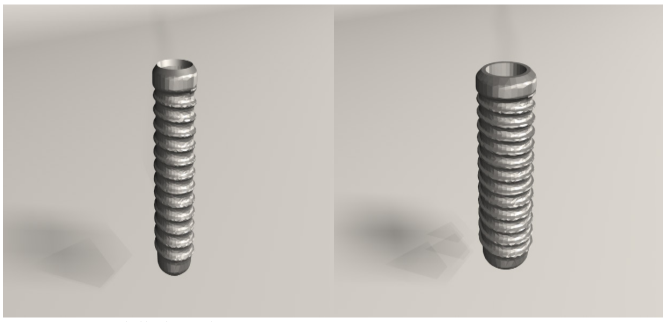

**Figure 3.** Modelled implants

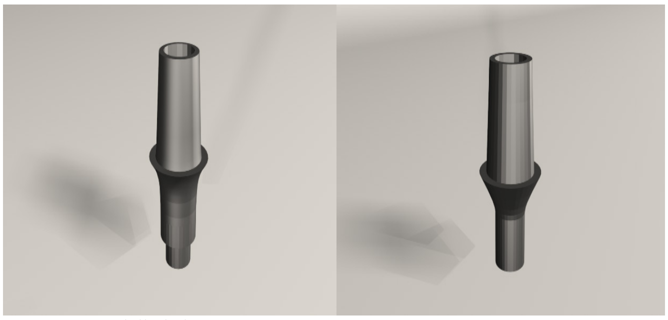

**Figure 4.** Modelled abutments

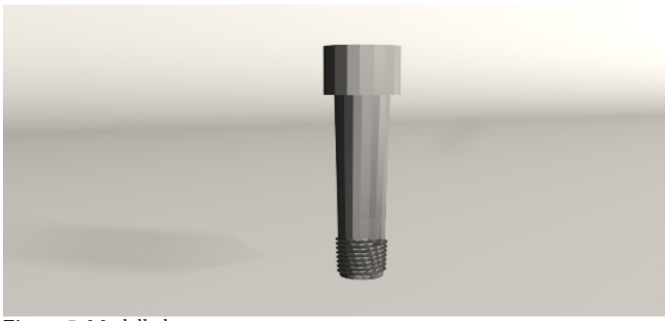

**Figure 5.** Modelled screws

**Modeling of implant supported fixed prosthesis:** A three-unit cement-retained implant-supported fixed prosthesis was designed in four different variations. To ensure standardization, all models maintained the same overall prosthesis and substructure thickness.

- ***Group 1:*** Chrome-cobalt alloy (Bego, Bremen, Germany) framework with feldspathic porcelain (Ceramco II; Dentsply, Burlington, USA). The metal framework allowed for 1-2 mm of porcelain covering. Cervical margins were rounded with a minimum thickness of 0.8 mm.
- ***Group 2:*** Monolithic zirconia (BruxZir Solid Zirconia, USA) prosthesis with the same thickness as group 1.
- ***Group 3:*** Zirconia (Y-TZP) infrastructure (NobelProcera, Nobel Biocare AB, Gothenburg, Sweden) veneered with feldspathic porcelain. Cervical margins were also rounded with at least 0.8 mm thickness, and total prosthesis thickness matched the other models.
- ***Group 4:*** Monolithic polyetheretherketone (PEEK) prosthesis (Goodfellow), with the same overall thickness as the other groups.

The number of elements and nodes in each model is summarized in **Table 1**.

**Table 1. Number of elements and nodes in the models used**

| Model | Number of nodes | Number of elements |
|---|---|---|
| verticalCrco | 75.952 | 397.952 |
| obliqueCrco | 75.952 | 397.952 |
| verticalMonolithicZr | 50.632 | 248.320 |
| obliqueMonolithicZr | 50.632 | 248.320 |
| verticalZr | 75.952 | 397.952 |
| obliqueZr | 75.952 | 397.952 |
| verticalMonolithicPEEK | 50.632 | 248.320 |
| obliqueMonolithicPEEK | 50.632 | 248.320 |

In this study, both cortical and trabecular bone were assumed to be isotropic, homogeneous, and linearly elastic. The mechanical properties of the materials used are listed in **Table 2**.

**Table 2. Mechanical properties of the materials used in the study**

| Material | Young's modulus (GPa) | Poisson's ratio | Reference(s) |
|---|---|---|---|
| Titanium (implant, abutment, screw) | 110 | 0.35 | (12) |
| Cortical bone | 13.7 | 0.30 | (177) |
| Trabecular bone | 1.37 | 0.30 | (177, 178) |
| Chrome-cobalt alloy | 218 | 0.33 | (14, 179-181) |
| Feldspathic porcelain | 82.8 | 0.35 | (182, 183) |
| Monolithic zirconia | 210 | 0.35 | (184) |
| Zirconia infrastructure | 210 | 0.30 | (184) |
| PEEK | 4.10 | 0.40 | (185) |

In total, eight finite element analyses were conducted under two different loading conditions across four groups. As the results of finite element analysis are derived from mathematical modeling without variance, statistical analysis was not applicable. Instead, the focus was placed on the interpretation of cross-sectional images and evaluation of stress magnitudes and distributions at the nodes.

The stresses resulting from applied forces were classified as normal stresses (tensile and compressive, represented by σ) and shear stresses (represented by τ). The greatest stress values in 3D elements occur when all shear components are zero. In the analysis, positive values represent tensile stresses, while negative values indicate compressive stresses. The prevailing type of stress (tensile or compressive) is determined by the greater absolute value and is used for interpretation.

Principal stress values are particularly important for brittle materials. Failure is expected when the maximum principal stress reaches or exceeds the tensile strength, or when the absolute value of the minimum principal stress reaches or exceeds the compressive strength.

## RESULTS

In this study, stress distribution was analyzed under vertical and oblique loading in four different prosthetic designs. Von Mises stress values were recorded for implants, abutments, screws, and superstructures. Principal stress values were assessed in the cortical bone.

### Vertical Loading Findings

Vertical loads of 1000 N were applied perpendicularly (90°) to the occlusal surfaces at three points across the molar and premolar units.

**Von Mises stress values under vertical loading:** The stress values in the implant components and prosthetic structures are summarized in **Table 3**.

**Table 3. Von Mises stress values under vertical forces**

| Group | Component | Von Mises stress (N/mm²) |
|---|---|---|
| Group 1 | Superstructure (connector area) | 24.81 |
| | Abutment (cervical region) | 361.68 |
| | Titanium screw | 131.68 |
| | Titanium implant (neck region) | 199.04 |
| Group 2 | Superstructure (cervical region) | 90.82 |
| | Abutment (cervical region) | 356.44 |
| | Titanium screw | 125.45 |
| | Titanium implant (neck region) | 196.26 |
| Group 3 | Superstructure (connector area) | 25.11 |
| | Abutment (cervical region) | 361.54 |
| | Titanium screw | 131.51 |
| | Titanium implant (neck region) | 199.16 |
| Group 4 | Superstructure (connector area) | 90.82 |
| | Abutment (cervical region) | 356.44 |
| | Titanium screw | 125.45 |
| | Titanium implant (neck region) | 196.26 |

**Principal stress values in cortical bone under vertical loading:** The stress values in the implant components and prosthetic structures are summarized in **Table 4**.

**Table 4. Principal stress values under vertical loading**

| Group | Maximum (MPa) | Minimum (MPa) |
|---|---|---|
| 1 | 3.48 | -28.65 |
| 2 | 3.49 | -28.17 |
| 3 | 3.48 | -28.67 |
| 4 | 3.34 | -30.93 |

### Oblique Loading Findings

An oblique force of 500 N at 30° was applied to simulate parafunctional occlusal loading. Stress concentrations were found to be significantly higher compared to vertical loading.

**Von Mises stress values under oblique loading:** Stress values under oblique forces are shown in **Table 5**.

**Table 5. Stress values under oblique forces**

| Group | Component | Von Mises stress (N/mm²) |
|---|---|---|
| Group 1 | Superstructure (cervical region) | 88.27 |
| | Abutment (cervical region) | 1706.35 |
| | Titanium screw | 449.20 |
| | Titanium implant (neck region) | 940.11 |
| Group 2 | Superstructure (cervical region) | 415.76 |
| | Abutment (cervical region) | 1680.53 |
| | Titanium screw | 452.32 |
| | Titanium implant (neck region) | 938.00 |
| Group 3 | Superstructure (cervical region) | 90.53 |
| | Abutment (cervical region) | 1707.73 |
| | Titanium screw | 449.04 |
| | Titanium implant (neck region) | 940.91 |
| Group 4 | Superstructure (cervical region) | 52.74 |
| | Abutment (cervical region) | 2376.10 |
| | Titanium screw | 479.78 |
| | Titanium implant (neck region) | 1290.96 |

**Principal stress values in cortical bone under oblique loading:** Stress values around the implant neck are summarized in **Table 6**.

**Table 6. Stress values around the implant neck**

| Group | Maximum (MPa) | Minimum (MPa) |
|---|---|---|
| 1 | 87.81 | -108.46 |
| 2 | 86.79 | -108.76 |
| 3 | 87.88 | -108.43 |
| 4 | 114.00 | -126.49 |

## DISCUSSION

According to numerous studies, one of the most important factors affecting the short- and long-term success of implant treatments is biomechanics.[16-18] Oblique loading generates higher stresses than vertical loading, highlighting the clinical importance of load direction in implant planning.[4,5]

Unlike natural teeth, dental implants do not have periodontal ligaments. Therefore, the forces exerted on the prosthesis are directly transmitted to the bone.[19,20] These forces should be considered during implant planning, and a homogeneous distribution of the loads on the bone must be ensured for successful outcomes. It has been reported that the material of the implant and prosthesis, their design, and the crown-to-implant ratio significantly influence these forces. Consequently, selecting appropriate implant and prosthesis options is critical for treatment success.[15,22-26]

Various methods can be used for stress analysis, each with its own advantages and limitations.[27,28] For example, the brittle varnish method does not provide numerical data, and strain gauge methods only measure stress at contact points. Laser beam and radiotelemetry methods are less commonly used due to practical challenges. The FEA method involves dividing the model into numerous small elements, analyzing each part separately, and then combining the results using mathematical equations. Many studies have emphasized the superiority of the FEA method compared to other techniques.[16,18,29-34]

Several FEA methods have been employed in implantology studies to investigate stress distribution.[35-37] Recent studies have utilized both two-dimensional (2D) and three-dimensional (3D) FEA to evaluate the impact of different prosthetic superstructure materials on stress distribution.[35,38] Among these, 3D FEA has been reported to offer more detailed and realistic analyses.[39-41]

Meijer et al.[42] and Clelland et al.[43] noted that the accuracy of FEA results is directly proportional to the number of nodes and elements in the model. For more realistic 3D FEA results, it is recommended to use at least 30,000 nodes and 200,000 elements.[44-46] In our study, a minimum of 50,000 nodes and 200,000 elements were used in each model.

Advanced digital imaging techniques are essential for obtaining accurate results in FEA.[11] These include computed tomography (CT), magnetic resonance imaging (MRI), and laser scanning. Among these, CT has been reported to produce the most detailed images.[47] Therefore, in our study, the mandibular model was created using CT imaging.

With the aid of constantly evolving technology, our models were designed to be as anatomically accurate and detailed as possible in three dimensions. Type 2 bone, as classified by Lekholm,[19] is typically found in the posterior mandible.[48-50] In our model, cortical bone thickness was set at 1.5 mm, and trabecular bone thickness was set at 13 mm, with implants placed in the posterior mandibular region.

Since implants lack the periodontal ligament, they transmit occlusal forces directly to the bone, differing significantly from natural teeth in this regard. Therefore, masticatory forces play a crucial role in maintaining the bone-implant interface.[23] Studies have demonstrated variability in occlusal forces. In this study, 1000 N of vertical force and 500 N of oblique force were applied. An angle of 30° was chosen for the oblique force, consistent with the literature.[48]

Metal-ceramic restorations remain the most commonly used prosthetic materials due to their durability, strong porcelain bonding, affordability, and accessibility. However, they also have disadvantages, including corrosion and potential allergic reactions. Other drawbacks include mismatches in thermal expansion coefficients between the metal and porcelain, discoloration due to silver content, and poor esthetics due to limited light transmission.[51]

Considering these limitations, we included metal-supported porcelain crowns (still regarded as the gold standard) in one of the experimental groups. Recently, zirconia-based ceramics with high durability and improved optical properties have gained popularity. Although zirconia has strong mechanical properties, it is veneered with glass ceramics due to its limited translucency. The most common issue with this type is the frequent detachment between the porcelain and zirconia layers.[52-56] To overcome this, newer monolithic materials have been developed, among which monolithic zirconia has demonstrated the best clinical performance.[52,54] Monolithic zirconia reduces stress concentrations and layer detachment, improving clinical performance in posterior implant restorations.[4]

Hybrid ceramics and PEEK have also been introduced to meet the demand for biocompatible and esthetically pleasing materials.[57] Due to its elastic properties, PEEK is believed to reduce occlusal forces and minimize stress transmission to implants. Thus, it may help solve stress-related problems.[58] Han et al.,[5] Almeida et al.,[6] and Schwitalla et al.,[21] reported that PEEK frameworks reduce prosthetic stress but may increase compressive stress in bone, which should be considered in patients with low bone density. It has been suggested that PEEK can serve as both an abutment and prosthetic material.[59] CAD-CAM-manufactured PEEK fixed prostheses have demonstrated higher fracture resistance compared to lithium disilicate glass ceramics (950 N), alumina (851 N), and zirconia (981-1331 N).[60,61]

Considering all this data, our study compared monolithic zirconia, zirconia-based porcelain, and PEEK materials via finite element stress analysis as potential alternatives to metal-ceramic restorations.

### Limitations

This study was conducted using FEA. Although FEA is an effective tool for simulating clinical scenarios, it has certain limitations. The materials were assumed to be homogeneous, isotropic, and linearly elastic, which may not fully represent the complexity of biological tissues. Clinical variables such as bone remodeling, fatigue loading, and patient-specific anatomical variations were not considered. Therefore, the results should be interpreted within the context of the simulation and need to be validated by clinical studies.

## CONCLUSION

- Oblique forces generated higher stress values than vertical forces.
- Under vertical forces, the lowest Von Mises stress in implants was observed with monolithic zirconia, and the highest with PEEK.
- In the premolar implant region, the highest abutment stress under vertical force was observed with metal-supported ceramic, and the lowest with monolithic zirconia.
- In the molar implant region, the highest abutment stress under vertical force was seen with PEEK, and the lowest with monolithic zirconia.
- In the premolar region under vertical force, the highest screw stress was observed with monolithic zirconia, and the lowest with PEEK.
- In the molar region under vertical force, the highest screw stress was found with PEEK, and the lowest with monolithic zirconia.
- Maximum stress in bridge restorations under vertical force was observed in monolithic zirconia, and minimum in metal-supported ceramic.
- Under oblique forces, the highest stress values in the premolar region abutments and screws were found with monolithic zirconia, and the lowest with PEEK.
- In the molar region under oblique forces, the highest stress in abutments and screws was observed with PEEK, and the lowest with monolithic zirconia.
- The highest bridge stress under oblique force was found with monolithic zirconia, and the lowest with PEEK.
- In the premolar implant region, bone stresses under both vertical and oblique forces were compressive, with maximum stress observed with PEEK and minimum with monolithic zirconia.
- In the molar implant region, bone stresses were also compressive, with maximum stress observed with monolithic zirconia and minimum with PEEK.

## ETHICAL DECLARATIONS


### Ethics Committee Approval

This study did not require ethical approval as it did not involve any human subjects or animal experiments.

### Informed Consent

Since the study was conducted without the participation of any living being, no written consent form was obtained.

### Referee Evaluation Process

Externally peer-reviewed.

### Conflict of Interest Statement

The authors have no conflicts of interest to declare.

### Financial Disclosure

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### Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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# Evaluation of AI-based chatbot responses to orthodontic retention-related patient questions: a comparative analysis

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## ABSTRACT

**Aims:** Orthodontic retention is a critical phase that requires long-term patient compliance and clear guidance. With the increasing use of digital platforms, patients often seek information online, but the accuracy and readability of such content remain questionable. This study aimed to evaluate and compare the quality, accuracy, and readability of orthodontic retention-related information provided by five AI-based chatbot platforms: ChatGPT-4, Copilot, Gemini, MediSearch, and OpenEvidence.

**Methods:** A set of 25 commonly asked patient-oriented questions on orthodontic retention was submitted to each Chatbot. Responses were evaluated using five key metrics: EQIP (ensuring quality information for patients), reliability score, global quality score (GQS), SMOG Readability Index, and Similarity Index. Mean±standard deviation values were calculated. Kruskal-Wallis and Dunn's post-hoc tests were used to assess statistical differences.

**Results:** MediSearch and OpenEvidence outperformed others in EQIP and Reliability scores. ChatGPT-4 generated the most original content with the lowest Similarity Index. SMOG readability was significantly better for ChatGPT-4, while MediSearch and OpenEvidence produced more technically complex language. Statistically significant differences ($p<0.05$) were found between platforms in EQIP, SMOG, and Similarity Index metrics.

**Conclusion:** Performance among AI chatbots varies significantly in delivering orthodontic retention guidance. While medical-specific tools offer superior accuracy and reliability, general-purpose models like ChatGPT-4 excel in readability and originality. The results highlight the importance of matching AI platform selection with patient communication goals.

**Keywords:** Artificial intelligence, Chatbots, orthodontic retention, health information quality, readability, patient education

## INTRODUCTION

Orthodontic retention represents a critical phase in the post-treatment period of orthodontic care, aimed at preserving the alignment and occlusion achieved through active treatment. As patients transition from fixed or removable appliances to retainers, they often have questions concerning appliance types, duration of wear, hygiene maintenance, and long-term outcomes. In recent years, the widespread use of digital platforms has made the internet a primary source of health information, particularly among orthodontic patients seeking guidance during the retention phase.[1-3] However, the accuracy, reliability, and readability of online content-especially when it lacks professional oversight-have become significant concerns in health communication.[4]

With the rapid evolution of natural language processing (NLP) and large language models (LLMs), AI-based chatbot systems have emerged as a new source of medical information. These tools offer conversational, user-friendly responses to a wide array of health-related queries and can provide 24/7 access to information, reducing barriers that traditionally hindered patient education.[5,6] Among them, general-purpose models such as ChatGPT-4, Microsoft Copilot, and Google Gemini are trained on massive text datasets and optimized for broad utility. In contrast, healthcare-specific chatbots such as MediSearch and OpenEvidence are designed to retrieve evidence-based medical content, often referencing peer-reviewed literature or guidelines provided by institutions such as the Mayo Clinic.[7,8]

Despite their increasing popularity, the quality and trustworthiness of chatbot-generated information in healthcare remain under scrutiny. Several recent studies have assessed AI tools in medical education, diagnostics, and patient communication, but findings have revealed issues including hallucinated content, outdated references, and variable reliability across different platforms.[9-11] Especially in orthodontics, where patients are often young and health literacy may vary, the complexity or vagueness of chatbot responses may negatively impact patient understanding or lead to misinformation.[12]

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A growing body of literature has evaluated chatbot performance using structured assessment tools. For instance, the ensuring quality information for patients (EQIP) tool, global quality score (GQS), and SMOG readability index have been applied to assess AI-generated patient education materials.[13-15] However, there is a notable lack of research that specifically addresses the chatbot-provided information in the context of orthodontic retention-a phase where long-term success is highly dependent on patient compliance and clear understanding.

This study aims to evaluate and compare the quality, reliability, readability, and similarity of AI-based chatbot responses to frequently asked questions related to orthodontic retention. By analyzing responses from five widely-used AI platforms-ChatGPT-4, Copilot, Gemini, MediSearch, and OpenEvidence-this study seeks to determine whether these tools can be considered suitable and safe sources of patient information. Furthermore, it explores the degree to which healthcare-specific models outperform general-purpose models in delivering accurate and comprehensible content. Given the increasing role of AI in health communication, this study will provide valuable insights for both clinicians and patients navigating the orthodontic retention process.

## METHODS

### Study Design and Ethical Consideration

This descriptive, cross-sectional study was designed to evaluate the quality, reliability, readability, and originality of responses provided by artificial intelligence (AI)-based chatbot platforms to frequently asked patient questions related to orthodontic retention. Since the study involved no human or animal subjects, clinical interventions, or identifiable patient data, ethics committee approval was not required. All procedures were carried out in accordance with the ethical rules and the principles.

### Selection of AI-Based Chatbots

Five AI-based chatbot platforms were selected based on their widespread use and accessibility in June 2025. These included:

**ChatGPT-4 (OpenAI, 2023):** A general-purpose large language model.

**Microsoft Copilot (Microsoft, 2024):** An AI assistant integrated into Microsoft 365.

**Google Gemini (Alphabet Inc., 2024):** A conversational AI tool with integrated web capabilities.

**MediSearch (MediSearch.io, 2023):** A healthcare-focused chatbot with evidence-based output.

**OpenEvidence (Mayo Clinic Platform Accelerate, 2023):** A healthcare-specific AI designed to retrieve clinical guideline-based information.

Among these, ChatGPT-4, Copilot, and Gemini are general-purpose LLMs, while MediSearch and OpenEvidence are trained or fine-tuned specifically for healthcare domains using Retrieval-Augmented Generation (RAG) frameworks.

### Question Generation and Categorization

To simulate real-life patient inquiries, 25 commonly asked questions related to orthodontic retention were generated through a review of publicly available patient education materials, orthodontic society guidelines, and online search queries (e.g., Google Trends, FAQ sections on orthodontic clinic websites) as shown in **Table 1**.

**Table 1. List of 25 frequently asked patient questions related to orthodontic retention, used to evaluate chatbot responses**

| No. | Question |
|---|---|
| 1 | What is orthodontic retention and why is it important? |
| 2 | How long do I need to wear my retainer? |
| 3 | What types of retainers are available after braces? |
| 4 | What is the difference between fixed and removable retainers? |
| 5 | Is it normal for teeth to shift slightly during retention? |
| 6 | How often should I wear my removable retainer? |
| 7 | What should I do if my retainer feels tight or loose? |
| 8 | How should I clean my retainer properly? |
| 9 | Can I eat or drink while wearing a removable retainer? |
| 10 | Is wearing a retainer at night sufficient for retention? |
| 11 | What are the signs that my retainer needs to be replaced? |
| 12 | What happens if I stop wearing my retainer too soon? |
| 13 | Can I get my retainer adjusted if it becomes uncomfortable? |
| 14 | How often should I visit my orthodontist during retention? |
| 15 | Are retainers covered by dental insurance? |
| 16 | What materials are used to make retainers? |
| 17 | Are there any side effects or risks of long-term retainer use? |
| 18 | What should I do if I lose or break my retainer? |
| 19 | Can retainers cause speech problems or discomfort? |
| 20 | Do I need a new retainer if I get dental work after braces? |
| 21 | Can retainers help correct minor relapse without full braces? |
| 22 | Is it safe to use online or mail-order retainers? |
| 23 | How do I store my retainer when not in use? |
| 24 | Can I use mouthwash to clean my retainer? |
| 25 | Is it okay to stop wearing my retainer after several years? |

The final set of questions covered various aspects of retention, including appliance types, usage duration, oral hygiene, complications, and long-term compliance.

All questions were phrased in plain English and designed to reflect the literacy level of a typical orthodontic patient or caregiver. Each question was input individually into a new conversation window for each chatbot, ensuring that no prior context influenced the response. For chatbots offering multiple response modes (e.g., “standard” vs. “detailed” in MediSearch), the most informative option (“detailed”) was selected for consistency across platforms.

### Evaluation Criteria

Each chatbot response was assessed using the following five metrics (**Table 2**):

**EQIP (Ensuring Quality Information for Patient):** A 20-item validated scoring system to evaluate the clarity, structure, and completeness of written health information.[1]

**Reliability Score (based on DISCERN):** A 5-Point Scale adapted from the DISCERN tool, focusing on transparency, source citation, and balance of information.[2]

**Global Quality Score (GQS):** A 5-point Likert Scale used to assess the overall quality, flow, and usefulness of the information for patients.[3]

**SMOG (Simple Measure of Gobbledygook):** A readability formula used to determine the educational level required to understand the response. Higher scores indicate more complex texts.[4]

**Table 2. Comparison of average EQIP, reliability, GQS, readability (SMOG), and originality (Similarity Index) scores among five AI chatbot platforms**

| Metric | ChatGPT-4 | Gemini | Copilot | MediSearch | OpenEvidence |
|---|---|---|---|---|---|
| EQIP | 13.6±1.4 | 12.8±1.6 | 13.1±1.3 | 16.2±1.0 | 15.9±1.2 |
| Reliability | 3.8±0.6 | 3.5±0.7 | 3.6±0.5 | 4.5±0.3 | 4.3±0.4 |
| GQS | 3.7±0.5 | 3.4±0.6 | 3.5±0.5 | 4.4±0.4 | 4.2±0.4 |
| SMOG | 11.4±1.0 | 11.9±1.2 | 12.0±1.1 | 12.8±1.1 | 13.1±1.2 |
| Similarity Index | 4.8±2.3 | 9.5±3.0 | 8.9±2.7 | 10.2±2.5 | 10.9±2.6 |

EQIP: Ensuring quality information for patients, GQS: Global quality score, SMOG: Simple Measure of Gobbledygook

**Similarity Index:** To evaluate the originality of the AI-generated content, all responses were submitted to iThenticate® plagiarism detection software. Scores were reported as percentages and categorized into:

- **0-10%:** High originality
- **11-20%:** Acceptable similarity
- **21-40%:** High similarity
- **40%:** Very high similarity

## Data Collection and Scoring Procedure

All chatbot responses were collected during July 2025. Each of the 25 questions was submitted separately to each of the five chatbots, resulting in a total of 125 responses. Two experienced orthodontists independently evaluated all responses according to the five predefined scoring criteria. Two experienced orthodontists independently evaluated all responses according to the five predefined scoring criteria. Any discrepancies were resolved by discussion and consensus.

## Statistical Analysis

Descriptive statistics (mean, standard deviation, median, minimum, maximum, and interquartile ranges) were calculated for each chatbot and each evaluation criterion. Normality of data distribution was assessed using the Shapiro-Wilk test. Since the data were not normally distributed, the Kruskal-Wallis test was used to detect statistically significant differences among chatbot platforms. If significance was detected, Dunn's post-hoc tests were applied for pairwise comparisons. Statistical significance was set at $p<0.05$. All statistical analyses were performed using Jamovi (Version 2.3; The Jamovi Project, Sydney, Australia; https://www.jamovi.org).

# RESULTS

Table 2 presents the descriptive statistics for each platform (mean±standard deviation).

## EQIP

MediSearch (16.2±1.0) achieved the highest EQIP score, followed closely by OpenEvidence (15.9±1.2). Both healthcare-specific platforms significantly outperformed general-purpose chatbots.

## Reliability

MediSearch (4.5±0.3) and OpenEvidence (4.3±0.4) outperformed general-purpose chatbots, indicating higher trustworthiness and source citation.

## GQS

The highest median scores were observed for MediSearch (4.4±0.4) and OpenEvidence (4.2±0.4), suggesting better overall usefulness of the content.

## SMOG

OpenEvidence (13.1±1.2) and MediSearch (12.8±1.1) produced the most complex texts, while ChatGPT-4 (11.4±1.0) generated the most readable responses.

## Similarity Index

ChatGPT-4 (4.8±2.3) achieved the lowest similarity score, reflecting the most original content, while OpenEvidence (10.9±2.6) had the highest overlap with existing sources.

## Kruskal-Wallis Test Results

The Kruskal-Wallis test revealed statistically significant differences between chatbot platforms in the following metrics (Table 3):

- EQIP ($p<0.001$)
- Reliability ($p=0.021$)
- SMOG ($p=0.013$)
- Similarity Index ($p<0.001$)

No statistically significant difference was found for GQS ($p=0.099$).

**Table 3. Summary of significant findings from Kruskal-Wallis and Dunn's post-hoc tests comparing Chatbot platforms**

| Finding | p-value | Post-hoc results |
|---|---|---|
| EQIP | <0.001 | MediSearch > all others (OpenEvidence close second) |
| SMOG | 0.013 | ChatGPT-4 < OpenEvidence |
| Similarity Index | <0.001 | ChatGPT-4 < Gemini, Copilot, MediSearch, OpenEvidence |
| Reliability | 0.021 | MediSearch > Gemini, Copilot |

EQIP: Ensuring Quality Information for Patients, SMOG: Simple Measure of Gobbledygook

## Visual Analysis

Figure 1 EQIP scores showed that MediSearch and OpenEvidence significantly outperformed the other platforms ($p<0.001$).

Figure 2 reliability scores demonstrated consistently high values for MediSearch, with OpenEvidence also showing strong reliability.

Figure 3 GQS values were relatively stable across platforms, with MediSearch and OpenEvidence slightly higher despite the lack of statistical significance.

Figure 4 SMOG scores indicated that OpenEvidence responses were the most complex, while ChatGPT-4 responses were the most accessible.

Figure 5 similarity Index comparisons revealed ChatGPT-4 generated the most original content, while OpenEvidence produced the highest similarity, consistent with its evidence-based retrieval approach.

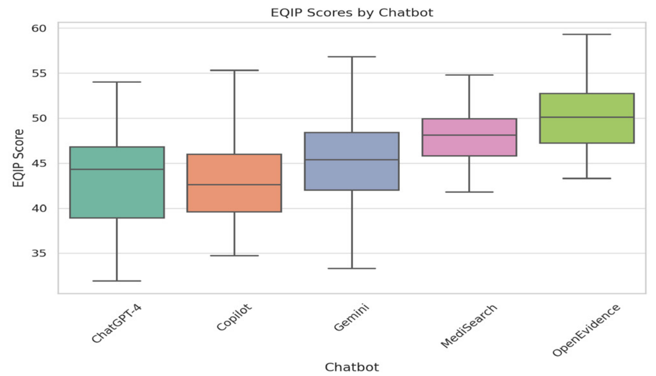


**Figure 1.** Box plot of EQIP scores by chatbot platform. MediSearch achieved the highest EQIP scores, followed closely by OpenEvidence, both significantly outperforming general-purpose chatbots (p<0.001)

EQIP: Ensuring quality information for patients

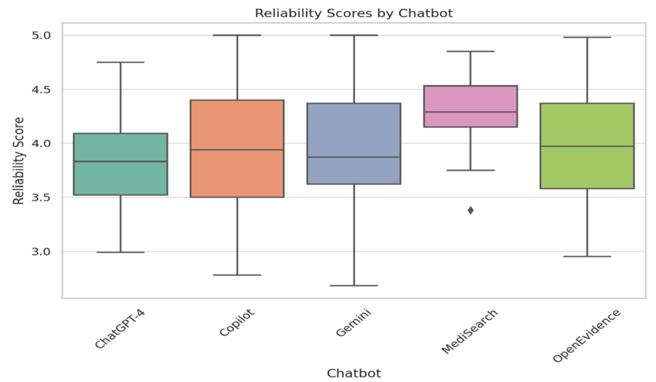


**Figure 2.** Box plot of reliability scores by chatbot platform. MediSearch demonstrated the highest reliability scores, with OpenEvidence also showing consistently strong results. General-purpose chatbots such as ChatGPT-4, Gemini, and Copilot showed lower and more variable reliability

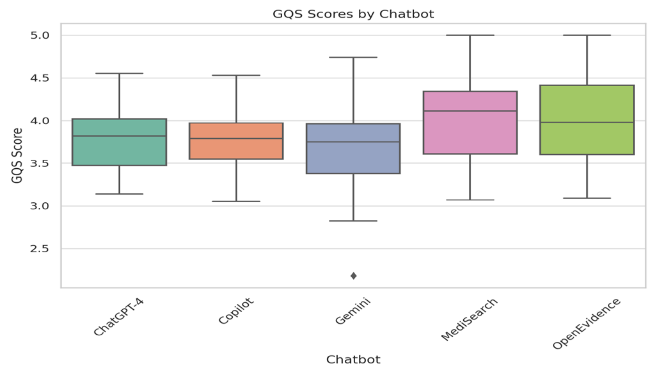


**Figure 3.** Box plot of GQS by chatbot platform. GQS values were relatively stable across all platforms, with MediSearch and OpenEvidence presenting slightly higher scores despite the absence of statistically significant differences

GQS: Global quality scores

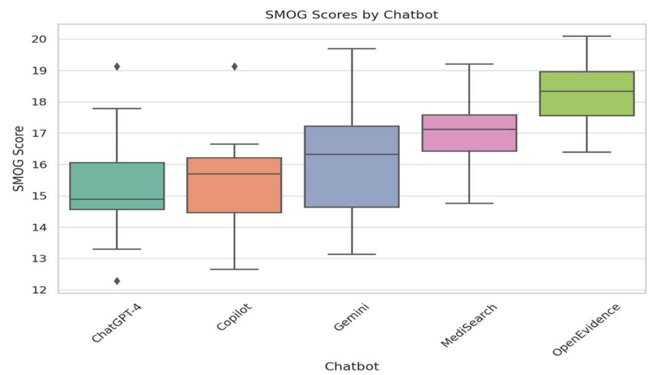


**Figure 4.** Box plot of SMOG readability scores by chatbot platform. ChatGPT-4 responses had the lowest SMOG scores, reflecting the most accessible and readable content. OpenEvidence and MediSearch responses showed the highest SMOG values, indicating greater linguistic complexity

SMOG: Simple Measure of Gobbledygook

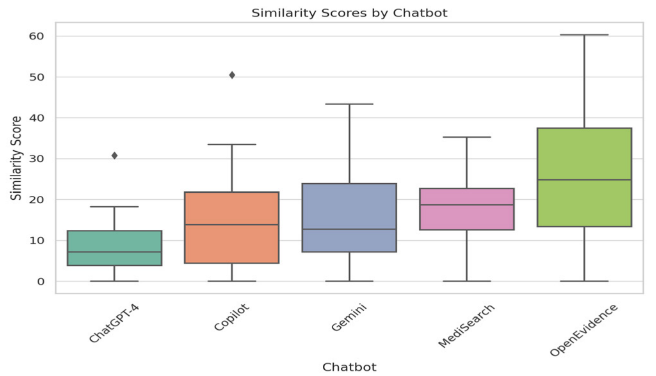


**Figure 5.** Box plot of Similarity Index scores by chatbot platform. ChatGPT-4 achieved the lowest similarity scores, reflecting the most original content. OpenEvidence demonstrated the highest similarity, consistent with its evidence-based retrieval approach

These findings suggest that while all platforms are capable of producing informative content, healthcare-specific platforms such as MediSearch and OpenEvidence provided more structured, evidence-based responses, whereas general-purpose chatbots such as ChatGPT-4 offered greater originality and readability.

# DISCUSSION

This study evaluated the performance of five AI-based chatbot platforms-ChatGPT-4, Copilot, Gemini, MediSearch, and OpenEvidence-on their ability to deliver patient-oriented information related to orthodontic retention. Using validated tools such as EQIP, Reliability Score, GQS, SMOG, and Similarity Index, the findings revealed marked differences across platforms in terms of content quality, readability, and originality.

Healthcare-specific platforms like OpenEvidence and MediSearch achieved significantly higher EQIP and Reliability scores. OpenEvidence's superior performance can be attributed to its underlying retrieval-augmented generation (RAG) framework that integrates evidence-based literature into real-time outputs.[4-6] Similarly, MediSearch, designed to function like a clinical search engine, demonstrated high GQS values, which likely stems from its emphasis on source citation and structural consistency.[7,8]

Conversely, ChatGPT-4, a general-purpose large language model, showed relatively lower EQIP and Reliability scores but delivered the most original and readable responses. Its lower Similarity Index aligns with prior studies highlighting its generative nature and variability in content output.[9] However, this benefit in originality may be offset by its tendency to produce hallucinated or unverifiable content, a documented concern in healthcare-related queries.[10,11]

Readability analysis using the SMOG Index showed a noteworthy disparity. Responses from OpenEvidence and MediSearch required a higher reading level (university or above), which may be less suitable for patients with lower health literacy.[12,13] This supports findings from earlier studies indicating that much of the digital orthodontic content is often too complex for the average patient.[14,15]

It is critical to consider that the ideal chatbot for patient education may not simply be the most accurate one. Studies by Denecke et al.[16] and Choudhury et al.[17] emphasize the role of user-centric communication-responses should be both trustworthy and relatable, particularly in emotionally sensitive phases such as retention, which requires long-term adherence to clinician instructions.

Platform-specific trade-offs were also evident. ChatGPT-4 and Gemini provided more conversationally engaging but less referenced responses, while OpenEvidence and MediSearch provided more structured but denser outputs. This duality echoes previous observations in patient-centered research, where emotional connection and clarity are often prioritized over technical depth.[18]

Our results are consistent with prior studies evaluating AI in orthodontic contexts, including orthognathic surgery,[19] periodontal therapy,[20] and temporomandibular disorders,[21] reinforcing the growing role of AI in dental patient education. However, this is one of the first studies focusing specifically on the orthodontic retention phase, a time when patient compliance plays a pivotal role in long-term treatment success.[22]

Several limitations must be noted. All interactions were conducted in English, which may not reflect chatbot performance in other languages.[23] Additionally, chatbot platforms are updated frequently, and this study represents a snapshot in time. Real-world patient queries may also vary in tone, clarity, and context-factors not fully simulated here.[24]

Furthermore, while the study utilized validated scoring tools, patient satisfaction and perceived helpfulness were not evaluated. These subjective measures could provide critical insights into chatbot effectiveness and should be considered in future research.[25]

### Limitations

Formal inter-rater reliability statistics (e.g., ICC) were not computed; instead, ratings were performed independently by two evaluators and finalized by consensus, which may limit generalizability.

## CONCLUSION

This study offers a comprehensive comparison of five AI-based chatbot platforms in their ability to provide accurate, reliable, and accessible responses to orthodontic retention-related patient questions. Among these, MediSearch and OpenEvidence, both healthcare-specific systems, consistently outperformed general-purpose chatbots in terms of information quality, reliability, and citation-based evidence. However, their responses were also characterized by increased complexity and reduced readability, potentially limiting their accessibility for the general patient population. Conversely, ChatGPT-4 and Gemini produced more conversational and original responses, with ChatGPT-4 demonstrating the lowest similarity index and highest ease of reading. These attributes may increase patient engagement but may also come at the cost of reduced factual transparency and reference traceability. Significant differences among chatbot platforms in EQIP, SMOG, and Similarity Index scores highlight the influence of underlying language model architecture and content sourcing strategies on information output. While AI chatbots hold promise as supportive tools in orthodontic education-particularly during the often-overlooked retention phase-they should not be viewed as substitutes for professional consultation. Instead, their optimal use lies in supplementing patient education with accurate, readable, and personalized information under clinical supervision. Future research should focus on the integration of adaptive language interfaces, multilingual support, and dynamic content validation mechanisms. These innovations will be essential in ensuring that AI-powered tools contribute meaningfully and ethically to the evolving landscape of patient-centered orthodontic care.

## ETHICAL DECLARATIONS

### Ethics Committee Approval

Since the study involved no human or animal subjects, clinical interventions, or identifiable patient data, ethics committee approval was not required.

### Informed Consent

Since the study was conducted without the participation of any living being, no written consent form was obtained.

### Referee Evaluation Process

Externally peer-reviewed.

### Conflict of Interest Statement

The authors have no conflicts of interest to declare.

### Financial Disclosure

The authors declared that this study has received no financial support.

### Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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Review

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# Current approaches to the diagnosis and management of bruxism

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## ABSTRACT

Bruxism is a repetitive motor activity characterized by involuntary movements of the masticatory muscles, such as clenching, grinding, or involuntary movements of the mandible, which may occur during sleep or wakefulness. Bruxism usually has a multifactorial etiology; dopaminergic system dysfunction, psychological stress, genetic predisposition, and environmental factors are at the forefront in this process. Self-report, clinical examination, and device-assisted methods are used in combination in the diagnostic process. In order to manage bruxism effectively, it is of great importance to first determine the underlying etiological factors; the treatment process should be customized according to individual needs and carefully planned with a multidisciplinary approach. Treatment includes occlusal splints, *Botulinum* toxin applications, physical therapy, biofeedback, laser therapy, and cognitive-behavioral interventions; in addition, psychologically based approaches such as sleep hygiene and mindfulness meditation have shown promising results. This review provides a multidimensional evaluation of bruxism from its historical definition to current classifications, etiopathogenesis, clinical-radiological findings, diagnostic approaches, and treatment options.

**Keywords:** Bruxism, diagnosis, treatment

## DEFINITION AND CLASSIFICATION OF BRUXISM

Bruxism is a complex motor behavior characterized by involuntary activity of the masticatory muscles, which can be seen in both children and adults, and both its clinical definition and epidemiological characteristics have undergone significant changes over time. Frohman's[1] definition in 1931 is considered to be an important milestone that paved the way for the modern paradigm by demonstrating that bruxism cannot be explained solely by occlusal causes. In 1957, Nadler[2] drew attention to the psychogenic and psychosomatic aspects of bruxism; he argued that this behavior should be considered in a broader physiological and emotional context, not just a habit limited to teeth. Pavone[3] defined bruxism as one of the most common, complex, and destructive dental functional disorders in 1985; he emphasized that the diagnosis is difficult in the early stages due to the lack of valid and reliable diagnostic tools and that it can cause a wide range of negative effects such as temporomandibular disorders, tooth wear, muscle pain, and aesthetic losses. In the later period, Okeson[4] demonstrated that hard occlusal splints used in the management of nocturnal bruxism significantly decreased masticatory muscle activity, whereas soft splints could increase this activity in some individuals. In the early 2000s, Lobbezoo and Naeije[5] stated that the central nervous system plays an important role in the etiology of bruxism; factors such as smoking, alcohol, drug use, systemic diseases, and trauma were among the main factors. The definition and classification of bruxism have changed over time; in 2013, a simpler and more pragmatic definition was adopted by an international consensus. Accordingly, bruxism is defined as repetitive masticatory muscle activity characterized by clenching, grinding, and/or involuntary movements of the mandible. In line with this definition, bruxism is divided into two subtypes depending on the circadian rhythm; sleep bruxism and awake bruxism.[6] Sleep bruxism is characterized by rhythmic or non-rhythmic masticatory muscle activity that can also be observed in healthy individuals and occurs during sleep. Awake bruxism, on the other hand, is defined as a non-pathologic muscle activity that occurs with tooth contact or jaw movements during wakefulness.[7] The aim of this review is to present current literature information on the etiology, pathophysiology, prevalence, clinical and radiological findings, diagnostic methods, treatment and management of bruxism.

## BRUXISM PREVALENCE

The global prevalence of bruxism is reported to be 22.22% on average in both adult and pediatric populations. The prevalence of sleep bruxism is 21%, and the prevalence of awake bruxism is 23%. In polysomnography-based measurements, the prevalence of sleep bruxism increases up to 43%. Sleep bruxism is most common in North America (31%), followed by South America (23%), Europe (21%), and Asia (19%). Awake bruxism is most commonly reported in South America (30%), followed by Asia (25%) and Europe (18%). It has been reported that bruxism is more common in women, and sleep bruxism in women shows a significant relationship with age. Since there were not enough samples in Africa and Australia, these regions were not included in the study.[8]

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In a recent systematic review and meta-analysis study, the overall prevalence of awake bruxism in adults was found to be 15.44%; no significant difference was found according to gender, sampling method, and classification criteria.[9]

The prevalence of sleep bruxism in children is quite variable according to studies and has been reported between 3.5% and 40.6%. It was stated that the prevalence decreased with age and there was no significant difference between genders.[10]

In a study conducted in Istanbul, the self-reported prevalence of bruxism-related symptoms and their relationship with demographic variables were evaluated in 795 adult individuals. Among the participants, 45.7% reported teeth clenching and 21.6% reported tooth grinding. Women reported morning headache, difficulty opening the jaw, joint noise, and symptoms affecting daily life more frequently than men. In addition, tooth wear was observed more frequently in married individuals, while age and occupational groups showed significant differences in terms of teeth grinding, wear, and joint sounds. These findings suggest that bruxism may be related to stress-related living conditions (e.g., marital status and occupational factors).[11]

## ETIOLOGY AND PATHOPHYSIOLOGY OF BRUXISM

It is generally accepted that bruxism has a multifactorial etiology that includes both peripheral (morphological) and central (pathophysiological and psychological) factors. Although occlusal discrepancies and anatomical features of the orofacial region have been cited as the main causes in the past, these morphologic factors are now considered to play only a secondary role. Recent studies have revealed that bruxism is primarily a behavior regulated by the central nervous system, particularly the dopaminergic system. In addition, smoking, alcohol, substance abuse, systemic diseases, and psychological factors are among the factors that may be effective in the development of bruxism; however, many of these relationships have not yet been finalized. When the current findings are evaluated holistically, it is thought that bruxism is a behavioral pattern predominantly originating from the central nervous system, with environmental factors contributing at a secondary level.[5]

Morphologic and functional changes occur in some neural circuits in the brain due to chronic stress; such modification leads to weakening of neural pathways that provide orofacial muscle control, increased muscle tone, decreased pain threshold, and increased involuntary muscle activity. Furthermore, the stress-activated hypothalamic-pituitary-adrenal (HPA) axis leads to elevated circulating cortisol levels; this hormonal change can be physiologically confirmed by increased salivary cortisol levels. This imbalance facilitates the development of bruxism and turns it into a self-perpetuating cyclical process.[12]

Both psychological and genetic factors have been shown to be effective in the etiology of bruxism. In clinical evaluations, anxiety has been identified as an important risk factor for bruxism. In genetic analyses, NLGN1, RIMBP2, and LHFP genes were identified as new candidate genes that may be associated with bruxism. These findings support that bruxism develops through the central nervous system and pave the way for the development of new treatment approaches in terms of understanding the disease at the molecular level.[13]

In one study, the C allele of the rs2770304 SNP was identified as a potential genetic risk factor for sleep bruxism. No significant association was found with other SNPs. Additionally, no positive association was found between genetic variants and awake bruxism or both types of bruxism. These findings suggest that genetic predisposition may be specific to sleep bruxism.[14]

In the study conducted by Rintakoski et al.[15] on twins in Finland, a significant relationship was found between sleep bruxism and genetic factors; it was reported that this effect increased with age. In addition, the genetic contribution to the phenotypic variance associated with sleep bruxism was found to be higher compared to other clinical conditions such as temporomandibular disorders.

Stress and anxiety were considered common risk factors for both sleep bruxism and awake bruxism, while depression was shown to be significantly associated only with awake bruxism. Although no direct association was found with gender, age, and nationality, it is suggested that this may indirectly increase the risk of bruxism, as women report higher levels of stress, anxiety, and depression.[16]

## CLINICAL AND RADIOLOGIC FINDINGS ASSOCIATED WITH BRUXISM

The clinical symptoms of bruxism are quite diverse and cover a wide range affecting the mouth, jaw, and head-neck region. While dental pain and hot-cold sensitivity are among the frequently reported findings, chronic pain in facial muscles and tension-type headaches may develop due to intense muscle contractions. The sound caused by the teeth rubbing against each other is often not recognized by the individual but can be identified by those around them. Abnormal alignments may occur as a result of irregular wear on the teeth, and dentin may be exposed on the worn surfaces. In addition, enamel cracks, tooth fractures, and mobility may be observed. Symptoms such as stiffness in the temporomandibular joint (TMJ) region, pain, restriction in opening the mouth, and difficulty in chewing may accompany it, while ear pain is also reported in some cases.[17] Moreover, bone apposition in the jaw and hypertrophy of the masseter muscle have been reported in individuals with bruxism.[18] In a separate study, occlusal analyses performed in bruxism patients revealed that masticatory forces were not evenly distributed across the dentition.[19] Among the 50 patients evaluated, supercontacts were identified in 60%, and occlusal discrepancies were detected in 76%. Additionally, buccal mucosal hyperkeratosis was observed in 88% of the patients, with 77.3% of these lesions localized along the occlusal line. These findings suggest that bruxism may exert significant effects not only on skeletal and muscular structures but also on oral mucosal tissues.[19]

In individuals with bruxism, tooth malpositions, especially crowding, are observed more frequently. However, meta-analyses have revealed that bruxism does not show a statistically significant relationship with any type of Angle class malocclusion.[20] In the literature, it has been reported that awake bruxism is not directly associated with temporomandibular pain; however, it may lead to lower oral health-related quality of life with increased levels of anxiety and depression.[21]

On the other hand, both sleep bruxism (SB) and awake bruxism (AB) are considered to be important risk factors for temporomandibular disorders (TMD). It has been reported that TMD subtypes such as muscle disorders and reduced disc displacement are more common in individuals with SB and AB; especially AB shows a stronger association with arthralgia. In addition, limitations in jaw functions, increased pain levels, and psychological symptoms such as depression and anxiety are more prominent in these individuals.[22]

In recent years, bruxism has been considered a motor behavior that occurs under certain conditions rather than a pathological condition. It has also been suggested that it may have a physiological or protective function in some cases. In studies with polysomnography (PSG), the relationships between sleep bruxism and clinical outcomes such as tooth wear, TMD, and dental implant failure have not been clarified. Therefore, the need for a common interdisciplinary terminology and standardized tools (e.g., STAB) in the diagnosis and evaluation of bruxism has increased. Especially restorative and prosthodontists are recommended to shape their clinical approach by taking this conceptual change into account.[23]

The literature also highlights possible links between sleep bruxism and temporomandibular joint pathologies such as myofascial pain, arthralgia, disc displacement, and joint noises.[24]

## DIAGNOSTIC METHODS IN BRUXISM

According to the 2013 international consensus report, bruxism is divided into two basic subtypes. Sleep bruxism is characterized by rhythmic (phasic) or non-rhythmic (tonic) masticatory muscle activity observed in healthy individuals during sleep, while awake bruxism is defined by behaviors such as fixation or forward thrusting of the mandible with repetitive or continuous contact of the teeth during wakefulness. According to these definitions, bruxism is no longer considered a disorder in itself but as a risk factor or potentially protective behavior for some clinical conditions. Therefore, the diagnostic process should not only be based on clinical observation; it should include subjective evaluations such as self-report as well as objective measurement methods such as electromyography (EMG).[7]

The classification system proposed by Lobbezoo et al.[6] aims to define the reliability levels of methods used in the assessment of bruxism. Under this system:

- The diagnosis of "probable bruxism" is based solely on the individual's own statement.
- The diagnosis of "possible bruxism" requires both individual reporting and the presence of clinical findings.
- A "definite diagnosis" requires the use of advanced assessment tools.

Definitive sleep bruxism diagnosis requires self-report, clinical assessment, and polysomnography (PSG), preferably supported by audio or video recording, while definitive awake bruxism diagnosis requires EMG measurements with ecological momentary assessment (EMA) or experience sampling method (ESM) in addition to self-report and clinical examination.[6] This approach aims to progressively increase the accuracy of the diagnosis.

In current research, bruxism is often diagnosed as "probable" or "possible" using self-report scales or clinical observations. However, studies with a "definitive" diagnosis often involve the use of an EMG device.[25-27]

STAB (Standardized Tool for the Assessment of Bruxism), developed to evaluate bruxism more comprehensively, is the first standardized and multidimensional measurement tool in this field.[28] By addressing sleep and awake bruxism separately, STAB allows systematic evaluation of the presence, potential consequences, etiological factors, and accompanying clinical conditions of these behaviors. Combining objective tools such as self-report, clinical observation, and EMG, this system aims to perform risk analysis and relational analysis by evaluating masticatory muscle activity within a behavioral spectrum rather than making a diagnosis. In this way, STAB provides comparability and standardization in both clinical practice and scientific research.[28]

However, there is no consensus in the literature on the link between bruxism and tooth wear. Especially in studies evaluated with objective methods, this relationship has been reported to be fragile. This situation suggests that dentists should avoid making a diagnosis of bruxism based solely on the observation of wear and should not consider tooth wear alone as a determinant of bruxism.[29]

## TREATMENT AND MANAGEMENT OPTIONS

It is of great importance to make the correct diagnosis in order to manage bruxism effectively. Since occlusal disorders are considered as one of the possible causes of bruxism, occlusal splints to correct these disorders are among the frequently preferred treatment options. Although there is no definite consensus on the effectiveness of splint applications, it is emphasized that this method should be used to reduce secondary damages that may occur rather than eliminating the causes of bruxism.[30]

A recent systematic review examining interventions for bruxism revealed the effectiveness levels of different treatment strategies. Accordingly, the effect of pharmacological treatments, oral rehabilitation practices, and some other interventions were generally found to be insufficient or uncertain. The results of oral appliances (e.g., night plates) varied across studies. In contrast, biofeedback, physical therapy, laser applications, and especially *Botulinum* toxin injections have shown positive effects in reducing the frequency of bruxism episodes.[31] As a matter of fact, there are data that *Botulinum* toxin applications are effective in the treatment of bruxism.[32]

Another approach that has recently appeared in the literature has been respiratory muscle training. It has been shown that inspiratory muscle training, especially in patients with obstructive sleep apnea, reduces masseter muscle contractions and awakening episodes and thus may be a potentially effective method iny the treatment of sleep bruxism.

Psychological-based interventions such as sleep hygiene practices and mindfulness-based meditation have been reported to be effective in the management of sleep bruxism in children. It was concluded that these approaches applied for five weeks reduced the incidence of sleep bruxism in children by 46% and that these methods are accessible, safe, and effective. These findings point to the potential for the use of psychologically based complementary therapies in pediatric dentistry.[34]

Methods applied within the scope of physical therapy include electrotherapy, therapeutic exercises, muscle relaxation techniques, posture awareness, manual therapy, acupuncture, and cognitive behavioral therapy. It is stated that behavioral therapy in particular is important for physical therapists to integrate psychological and physical interventions in their practice. These approaches increase the clinical effectiveness of combined interventions based on the biopsychosocial health model and have been successfully used in the management of different conditions such as low back pain, neck pain, knee osteoarthritis, musculoskeletal pain, and oncologic conditions.[35]

In general, there are various treatment approaches in the management of bruxism. Biofeedback, physiotherapy, laser applications, and *Botulinum* toxin injections have shown promise in reducing the frequency of attacks. However, there is still insufficient scientific evidence on the long-term efficacy and safety of these treatments. Therefore, treatment planning should be based on individual needs, and the process should be carefully monitored.[36]

In a study conducted in children aged 6-12 years, the effects of laser acupuncture and relaxation-oriented physical therapy interventions in the treatment of bruxism were evaluated. The results showed that both interventions reduced pain, increased mouth opening, and improved masticatory muscle activity (maximum voluntary contraction). Compared to sleep hygiene, laser and physical therapy applications stand out as more effective and promising interventions.[37]

## CONCLUSION

Bruxism requires a holistic evaluation that goes beyond an approach that focuses only on dental findings in both children and adults, including behavioral, psychological and neurophysiological elements. Bruxism is a multifactorial disorder influenced by the central nervous system, environmental factors, genetic factors, and psychological factors. Treatment options include oral appliances, laser applications, *Botulinum* toxin injections; physical therapy methods such as electrotherapy, therapeutic exercises, muscle relaxation techniques, posture awareness, manual therapy, acupuncture and cognitive behavioral therapy; inspiratory muscle training in patients with obstructive sleep apnea; psychological interventions such as sleep hygiene practices and mindfulness-based meditation and biofeedback. In conclusion, the treatment strategy for bruxism should be determined based on the underlying causes and individual clinical profiles, and treatment options should be developed based on a multidisciplinary evaluation and follow-up process.

## ETHICAL DECLARATIONS

### Referee Evaluation Process

Externally peer-reviewed.

### Conflict of Interest Statement

The authors have no conflicts of interest to declare.


### Financial Disclosure

The authors declared that this study has received no financial support.


### Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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Case Report

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# Management of amlodipine-induced gingival overgrowth and 1-year follow-up results: case report

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## ABSTRACT

Gingival overgrowths are very common in clinical practice and are often described as reactive hyperplasia caused by plaque-induced gingival disease. Accurate diagnosis of the cause of gingival overgrowth is very important in determining the treatment to be applied to the patient. The cause of drug-induced gingival overgrowth is not fully understood and is thought to be a complex process affected by different inflammatory and non-inflammatory mechanisms. This case report aims to emphasize the rare occurrence of amlodipine-induced gingival hyperplasia and the lack of oral hygiene that exacerbates this condition. A 40-year-old woman presented to our clinic with gingival bleeding, pain and gingival enlargement. It was learned from her anamnesis that she had hypertension and used 10 mg amlodipine daily. The patient was found to have lack of oral hygiene, gingival bleeding, edema, hyperplasia, and radiographic bone loss. Along with the initial periodontal treatment (scaling, root planning, oral hygiene education), cardiology consultation was requested and medication was changed. Afterwards, the patient underwent gingivectomy and gingivoplasty procedures. In the long-term follow-up of the patient, the results were seen to be permanent and satisfactory.

**Keywords:** Amlodipine, gingival overgrowth, calcium channel blocker, gingivectomy, gingivoplasty

## INTRODUCTION

This condition, which is characterized by abnormal overgrowth of gingival tissues, can be caused by different etiologies, including inflammatory, drug-induced, systemic and hereditary.[1] Drug-induced gingival overgrowth tends to occur in the anterior regions, starting at the interdental papilla and may eventually cover the entire surface of the teeth.[2,3] It can occur in the periodontium with or without alveolar bone loss and is not associated with attachment loss. There is a tight and fibrotic gingival appearance. The tissue may become bleeding and red with a secondary infection that will occur with increased plaque accumulation.[4]

As a result of severe gingival overgrowth, plaque retention increases and the patient cannot maintain oral hygiene.[5] Progression of this condition brings about inflammatory periodontal diseases. Patients may experience pain and chewing problems as well as aesthetically undesirable images.[1]

Anticonvulsant drugs used in the treatment of epilepsy (phenytoin), calcium channel blocker antihypertensive drugs with different chemical structures such as dihydropyridines (nifedipine, amlodipine), benzodiazepine derivatives (diltiazem), phenylalkylamine derivatives (verapamil), and immunosuppressant such as cyclosporine A are drugs that cause gingival enlargement. The clinical lesions and histopathologic conditions that all of these drugs cause in the gingiva are very similar and very difficult to distinguish.[6,7] It is known that growth occurs within 3 months following the use of these drugs.[8] The mechanism underlying this growth has not yet been fully elucidated, but a multifactorial etiology is thought to be involved, with some predisposing factors such as age, genetic predisposition and plaque control.[9]

Calcium channel blockers, which are among the frequently preferred options in the treatment of cardiovascular diseases (hypertension, cardiac arrhythmia, angina pectoris and coronary artery spasm, etc.), are among the drugs that affect gingival growth.[5,10] This drug, which acts on voltage-gated $Ca^{+2}$ channels in the plasma membrane, is frequently prescribed and has antihypertensive, antianginal and antiarrhythmic effects.[10] The effects of these drugs on gingival growth vary depending on the type and dose of the active substance. Among calcium channel blockers, nifedipine is the drug most commonly associated with gingival enlargement. Amlodipine is a dihydropyridine derivative with fewer side effects than nifedipine, and the gingival overgrowth associated with this drug is less than with other calcium channel blockers (1.7%-3.3%).[11,12]

Two treatment approaches, surgical and non-surgical, have been described for the treatment of gingival enlargement.[13] For an effective treatment, first of all, the patient's cardiologist should be contacted and, if possible, discontinuation of the medication or change to another group of medications should

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be requested. The calculus and dental plaque present in the mouth should be professionally removed, scaling, subgingival curettage and root planning should be performed.[14] Oral hygiene education should be given to patients and doctor controls should be increased. Before treatment, faulty restoration edges that are likely to increase the effect of gingival growth should be corrected, and any orthodontic brackets or bands should be removed.[7] Anti-inflammatory mouthwash may be prescribed in addition to the initial treatment to reduce inflammation. Patients with gingival overgrowth can generally recover without surgery, but there may be cases where surgery is required.[11]

This case presentation discusses the clinical characteristics, etiology, initial treatment, and surgical approach to drug-induced gingival hyperplasia in a patient who had been taking amlodipine for more than three years due to hypertension. Changes that have occurred over a period of more than one year have been observed and reported in detail.

## CASE

The patient was admitted to Dicle University, Faculty of Dentistry, and Department of Periodontology with the complaints of gingival enlargement, bleeding and pain. As a result of the anamnesis, it was learned that the patient was a non-smoker, hypertensive and used the 10 mg amlodipine-containing drug once a day. Clinical and radiologic examination revealed bleeding on probing and fibrotic growths on the gingiva especially in the anterior regions. Inflammation due to calculus and plaque accumulation was observed with the severity of the growth. Increased pocket depth and radiologic bone loss were detected (**Figure 1**).

**Figure 1.** Intraoral image of patient before the initial treatment

The patient was given oral hygiene training along with scaling and subgingival curettage procedures. A consultation was requested from the patient's cardiologist to change the hypertension medication. As a result of the consultation, the patient's medication was changed to a different drug. The patient was recalled one week later and the subgingival curettage and root planing procedures were repeated. An anti- inflammatory mouthwash was prescribed and a follow-up appointment was scheduled for six weeks later.

When the patient returned six weeks later, bleeding in the gums had decreased, oral hygiene had improved to an acceptable level and the tissues had a more fibrotic appearance (**Figure 2**). Curettage of the unhealed areas was repeated and the patient was called for check-ups at different times (**Figure 3**).

Although the patient's complaints such as inflammation findings, pain and bleeding disappeared, gingivectomy and gingivoplasty were planned due to the presence of fibrotic tissues and irregular shape of the gums (**Figure 4**).

**Figure 2.** Intraoral image of the patient after six weeks

**Figure 3.** Intraoral images of the patient after six months

**Figure 4.** Intraoral image of the patient after gingivectomy and gingivoplasty

Long-term follow-up of the patient showed that the treatment results were permanent and satisfactory (**Figure 5, 6**).

**Figure 5.** Intraoral image of the patient one month after surgery

**Figure 6.** Intraoral image of the patient one year later

## DISCUSSION

Gingival overgrowth caused by medications is a side effect of the drug outside the target tissue.[15] Recent studies have shown that gingival overgrowth is common, especially in patients who have been taking antihypertensive drugs for more than 5 years, with a rate of 77%.[16] Calcium channel blockers, which have been found to stimulate gingival fibroblasts by inhibiting intracellular calcium uptake, also cause gingival enlargement as a side effect.[17] However, not all patients develop gingival overgrowth at the same rate. The presence of periodontal inflammation due to lack of oral hygiene and the presence of fibroblasts that are highly sensitive to drugs cause gingival overgrowth to develop at different rates among patients.[5,18]

The dose of the drug used, the duration of treatment, the concentrations of the drug in saliva and gingival groove fluid directly affect the severity of drug-induced gingival overgrowth. Amlodipine, a third generation dihydropyridine calcium antagonist, is a drug of choice in the treatment of cardiovascular diseases.[11,19]

Many studies have shown that amlodipine does not cause gingival hyperplasia when administered at a dose of 5 mg once daily for more than 6 months, and that gingival hyperplasia only occurs when a dose of 10 mg of amlodipine is administered daily.[18] Jorgensen et al.[5] reported in their study of 150 patients who used 5 mg of amlodipine daily for at least 6 months that the use of 5 mg of amlodipine did not cause gingival hyperplasia.

Contrary to these studies, other studies have reported that a daily dose of 5 mg causes gum growth.[5] There are publications stating that gingival overgrowth develops faster, more severely and more frequently in patients taking 10 mg daily than in those taking lower doses.[17] In patients taking 10 mg amlodipine daily, interdental papillae are affected and begin to grow within 3 months after starting the drug.[5]

Amlodipine, a calcium channel blocker, causes less enlargement compared to nifedipine.[20] However, none of the other group of anti-hypertensive drugs that are not calcium channel blockers are known to cause gingival enlargement. Therefore, the first step in treatment should be to change the patient's medication to another non-growing drug if possible. With this treatment approach, resolution of gingival lesions may take 1-8 weeks.[19]

Our patient has been taking amlodipine 10 mg daily for about 3 years and brushes her teeth 3 times a week. With gingival overgrowth, she has difficulty performing oral hygiene procedures. The patient's medication was changed to a different drug by the cardiologist. Gingival overgrowths can have a variety of causes and it is very important to determine their etiology.[21]

An important risk factor for the development of drug-induced gingival overgrowth is poor oral hygiene.[17,22] The resulting gingival overgrowth not only causes aesthetic problems but also causes speech and chewing difficulties, impairs oral hygiene and leads to malnutrition.[11,23]

Professional debridement treatment with supragingival and subgingival scaling is recommended to alleviate the severity of gingival overgrowth.[22,24] Non-surgical periodontal treatment aims to restore health, function and aesthetic appearance to the periodontium as well as controlling inflammation due to dental plaque. Therefore, teaching an effective oral hygiene technique, subgingival debridement and root planning play an important role in the treatment. The addition of a 0.12% chlorhexidine mouthwash to the treatment can contribute positively to the outcome.[25]

If gingival enlargement persists despite medication changes and good plaque control, periodontal surgery is necessary in these cases. Necessary consultations and precautions are taken for the surgical procedure and interventions such as gingivectomy, periodontal flap surgery, laser excision can be considered depending on the physician's decision.[11] The size of the area to be operated on, the presence of bony defects and periodontitis should be considered. If the patient has mental health problems, is a pediatric patient or has a bleeding problem, electrosurgery and laser surgery can offer significant advantages.[26]

Although an effective result was obtained as a result of meticulous application of oral hygiene procedures, control of dental biofilm and non-surgical periodontal treatment after the medication change, classical gingivectomy and gingivoplasty were performed with a scalpel in a small area due to ongoing irregularities and deformities in the gingiva.

## CONCLUSION

In this case report, it was demonstrated that long-term use of 10 mg of amlodipine is associated with gingival overgrowth. However, lack of oral hygiene and periodontal inflammation increased the severity of the growth. In hypertensive patients at risk of gingival overgrowth, medication changes should be made, if possible, effective oral hygiene education and non-surgical periodontal treatment should be applied to the patient. If these methods are inadequate, surgical intervention is recommended.

## ETHICAL DECLARATIONS

### Informed Consent

All patients signed and free and informed consent form.

### Referee Evaluation Process

Externally peer-reviewed.

### Conflict of Interest Statement

The authors have no conflicts of interest to declare.


### Financial Disclosure

The authors declared that this study has received no financial support.


### Author Contributions

All of the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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