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REVIEW

Diagnosis and Treatment Approaches of Dentists Regarding Peri-Implant Diseases. A Questionnaire Study

Diş Hekimlerinin İmplant Çevresi Hastalıklarla İlgili Tanı ve Tedavi Yaklaşımları. Bir Anket Çalışması

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ABSTRACT

INTRODUCTION: To determine the approach for diagnosis and treatment of peri-implant diseases in general dentists and to test whether graduation times make a difference in these approaches.

MATERIAL and METHODS: The survey consisting of four sections was filled out by 381 dentists on online.anketler.com. The first part included demographics, second section included questions about the characteristics of peri-implant mucosa and diagnosis of peri-implant diseases; third section included questions about the treatment of peri-implant diseases; and fourth section included questions about risk factors. R software for statistical analyzes was used.

RESULTS: There were no significant differences in responses regarding peri-implant mucosa characteristics and peri-implantitis risk factors according to graduation time (p>0,05). Although responses regarding peri-implantitis treatment options were generally similar (p>0,05), differences were observed in local antiseptic and systemic antibiotic use among the study groups (p<0,001, p=0,021, respectively). Differences were also observed in responses to options of surgical/resective/regenerative treatments among the study groups (p<0,03, p=0,004, p<0,018, respectively). Undergraduate education as a source of information was reported as 88,6% among recently graduated dentists and 29,9% among older dentists (p<0,05).

CONCLUSION: It would be beneficial to organize more and comprehensive training courses and seminars on peri-implant diseases for dentists who graduated a long time ago.

Keywords: *Peri-implant mucositis, peri-implantitis, questionnaire*

ÖZ

GİRİŞ: Uzmanlığı/doktorası olmayan diş hekimlerin implant çevresi hastalıkların tanı ve tedavi sürecindeki yaklaşımlarının belirlenmesi ve mezuniyet zamanlarının bu yaklaşımlarda fark yaratıp yaratmadığını test etmek amaçlanmıştır.

YÖNTEM ve GEREÇLER: Dört bölümden oluşan anketimiz onlineanketler.com platformunda 381 diş hekimi tarafından dolduruldu. Anketin ilk bölümünde tanıtıcı bilgi soruları yer aldı. İkinci bölümde implant çevresi mukozanın özellikleri ve implant çevresi hastalıkların tanısı hakkında; üçüncü bölümde bu hastalıkların tedavisi hakkında; dördüncü bölümde ise risk faktörleri hakkında sorular yer aldı. İstatistiksel analizler için R yazılımı kullanıldı.

BULGULAR: İmplant çevresi mukozada olması gereken özelliklere ve peri-implantitis risk faktörlerine yönelik cevaplarda diş hekimlerinin mezuniyet zamanına göre bir fark saptanmadı (p>0,05). Araştırma grupları arasında peri-implantitis tedavisine yönelik verilen cevaplar genellikle benzer olmasına karşın (p>0,05) lokal antiseptik ve sistemik antibiyotik kullanımına yönelik cevaplarda farklılıklar izlendi (p<0,001, p=0,021, sırasıyla). Cerrahi debridman, rezektif ve rejeneratif tedaviye yönelik yanıtlarda da mezuniyet zamanlarına göre farklılıklar izlendi (p<0,03, p=0,004, p<0,018, sırasıyla). Son 5 yıl içerisinde mezun olan katılımcılar bilgi kaynağı olarak %88,6 oranında üniversite eğitimini bildirirken mezuniyetinden beri 10 yıldan fazla zaman olmuş katılımcılar bilgiyi sadece %29,9 oranında lisans eğitiminden edindiklerini bildirdiler (p<0,05).

SONUÇ: Uzun zaman önce mezun olmuş hekimler için implant çevresi hastalıklar hakkında daha fazla ve kapsamlı eğitim programları, kurs ve seminerler düzenlenmesi faydalı olacaktır.

Anahtar Kelimeler: *Peri-implant mukozitis, peri-implantitis, anket*

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INTRODUCTION

Dental implants are considered a suitable treatment option for partial and complete edentulism. Along with the increasing number of implant procedures, the prevalence of peri-implant diseases has also risen.[1,2] Peri-implant diseases are defined as peri-implant mucositis, peri-implantitis, and defects in the surrounding hard and soft tissues.[3] Various treatment approaches, including resective, reconstructive, or combined therapies, may be preferred.[4-7] Despite these differing approaches, achieving complete resolution of the disease is challenging, and recurrence may occur after treatment.[4] There is no universally accepted procedure for treating peri-implant diseases.[1,8] Accurate diagnosis, appropriate application of treatment methods, knowledge of potential risk factors, and modification of these factors to promote implant health are crucial for the management of peri-implant diseases.[9-11]

The widespread use of dental implants has been accompanied by an increased incidence of peri-implant diseases.[12] Given this, it is important for dental graduates to possess adequate knowledge of peri-implant diseases. In the core curriculum of dental education, the learning objectives for peri-implant mucositis are defined as "the ability to diagnose, treat, or manage treatment" and "the ability to perform preventive dentistry interventions," while for peri-implantitis, they are "the ability to diagnose and possess knowledge of treatment, including referral to a specialist after performing necessary preliminary procedures" and "the ability to carry out preventive dental procedures." This curriculum was first approved by the Higher Education Council (YÖK) in 2016.[13] However, not all universities have simultaneously implemented this program. Delays and gaps in the curriculum regarding peri-implant diseases present a challenging factor for dental professionals who have not received specialized or doctoral training in the field.

The difficulties in treating peri-implant diseases underscore the importance of timely diagnosis and modification of risk factors in favor of implant health. From a preventive dentistry perspective, dentists must be able to diagnose peri-implant diseases, refer patients for treatment, and manage risk factors to prevent the occurrence of such diseases. The increasing number of patients referred to our faculty for peri-implantitis treatment has raised the need to assess the knowledge and competence of general dentists who do not have specialized or doctoral training in this field. Based on this, a survey was conducted to examine the approaches and knowledge levels of these dentists regarding the diagnosis and treatment of peri-implant diseases, as well as whether differences in their approach exist based on the time of their graduation.

MATERIALS AND METHODS

The survey study aimed at examining the approaches of dentists toward peri-implant diseases was approved by the Medical Research Ethics Committee of the Faculty of Medicine, Ege University, on October 22, 2020, with decision number 20-10.IT/11. After receiving ethical approval, the survey was conducted with 381 dentists via the platform "onlineanketler.com." The questionnaire used in the study was created by the authors for this research.

Inclusion and Exclusion Criteria

For participation in the survey, it was considered a requirement that dentists had no specialty or doctoral training in any field of dentistry. Participation in the survey was voluntary. Dentists with specialty or doctoral education in any area of dentistry were excluded from the study. Dentists who did not wish to complete the survey or accept the informed consent form were also excluded.

Questionnaire

The questionnaire designed to collect data in this study consisted of 20 questions, including one open-ended and 19 closed-ended items. In the first section of the survey, participants were asked questions regarding their age, gender, years since graduation, where they practice dentistry, sources of information on peri-implant diseases, and how they manage treatment when encountering peri-implant diseases. The second section contained questions about the characteristics of peri-implant mucosa and the diagnosis of peri-implant diseases. The third section focused on questions related to the treatment of peri-implant diseases, while the fourth section addressed questions concerning risk factors for peri-implant diseases. The final question was an open-ended question about peri-implant diseases.

Data Collection

Data for this study were collected between January 4, 2021, and July 29, 2022. The survey was created on the "onlineanketler.com" platform, and participants were provided with a link to access the survey online. The surveys were collected anonymously. At the beginning of the survey, before participants could proceed to the questions, an information section was included to explain the purpose and confidentiality of the study. Participants were required to check a consent box to proceed with the survey. To prevent dentists with specialized or doctoral degrees from completing the survey, those who selected "Yes" to the question "Do you have a specialty/doctoral degree?" were blocked from accessing the survey questions and redirected to the end of the survey.

Statistical Analysis

Based on the estimated number of 400,000 dentists in Turkey, it was determined that a sample size of at least

381 participants would be sufficient to predict the correct answer rate for any question in the survey at a 95% confidence interval with a lower limit of 45% and an upper limit of 55% (Epi Info™, a database and statistics program for public health professionals. CDC, Atlanta, GA, USA, 2011). Descriptive statistics, including frequencies and percentages, were provided for categorical variables. Statistical significance was considered at $p<0.05$, and all statistical analyses were performed using R software (R software, version 4.0.5, package: arsenal, R Foundation for Statistical Computing, Vienna, Austria; http://r-project.org). The relationship between two categorical variables was analyzed using Pearson's chi-square test (simulated p-value was used when applicable).

RESULTS

The survey was completed by 381 individuals through an online platform. The evaluation was based on the responses provided by these 381 participants. To examine whether the time since graduation influenced the responses regarding the topics evaluated, participants were grouped into three categories based on their years since graduation: those who graduated within the last 5 years, those who graduated between 5-10 years ago, and those who graduated more than 10 years ago.

1. Demographic Findings of All Participants

Among the participants, 53.3% were female and 46.7% were male (Table 1). Regarding the time since graduation, 53% of the participants had graduated within the last 5 years, 13.6% had graduated 5-10 years ago, and 33.3% had graduated more than 10 years ago. As for their workplace, 31.8% worked in private practices, 29.4% in polyclinics, and 28.3% in public clinics. Concerning sources of information on peri-implant diseases, 67.5% of participants obtained their knowledge during their university education, 43.6% from courses and seminars, 42% through self-study, and 5.8% from other sources. A significant portion of the participants (44.1%) reported that they referred patients for peri-implantitis treatment.

Table 1. Demographics

Demographics	Total
Age (mean±SS/min-max)	34.0±11.6 / 24.0-73.0
Gender (Female/Male) (N (%))	203 (%53.3) / 178 (%46.7)
Years Since Graduation (N (%))	
≤5 years	202 (%53.0)
5-10 years	52 (%13.6)
≥10	127 (%33.3)
Place of Practice (N (%))	
Private Practice	121 (%31.8)
Private Polyclinic	112 (%29.4)
Public Clinics	108 (%28.3)
Not Practicing	40 (%10.5)
Source of Information on Peri-Implant Diseases (N (%))	
Undergraduate Education	257 (%67.5)
Courses and Seminars	166 (%43.6)
Self-research	160 (%42.0)
Other Sources	22 (%5.8)
Preference for Peri-implantitis Treatment (N (%))	
Primarily perform treatment themselves. rarely consult a specialist	97 (%255)
Rarely perform treatment themselves usually consult a specialist	96 (%252)
Refer patient	168 (%441)
Not Practicing	40 (%105)

2. Responses Regarding the Characteristics of Peri-implant Mucosa and Clinical Diagnosis of Peri-implant Diseases

The answers to these questions are presented in Table 2. The majority of participants (59.6%) believed that peri-implant mucosa should be keratinized. 52.8% of participants considered the presence of keratinized tissue less than 2 mm as a risk for peri-implantitis. 46.5% of participants stated that they used plastic probes because they believed plastic probes were necessary for diagnosis, while 32.8% indicated that, although they thought a plastic probe was required, they did not use it because it was unavailable in their clinic. The majority of participants (46.5%) indicated that they suspected peri-implantitis when the probing depth was 4 mm or more. They also stated that when there was more than 3 mm of bone loss in comparison to the initial bone level after 1 year of prosthetic restoration placement or when there was no radiographic evidence or probing measurements, they suspected peri-implantitis when bleeding occurred during probing (Table 2).

Table 2. Responses of All Participants to Questions Regarding the Characteristics of Peri-Implant Mucosa and the Clinical Diagnosis of Peri-Implant Diseases

Questions	Total
Most important characteristic of peri-implant mucosa	
Attached peri-implant mucosa	119 % (31.2)
Keratinized peri-implant mucosa	227 (%59.6)
Thick peri-implant mucosa in bucco-lingual direction	35 (%9.2)
Presence of keratinized mucosa around the implant	
If the amount of keratinized mucosa is less than 2mm, peri-implantitis develops	201 (%52.8)
Lack of keratinized mucosa does not affect peri-implantitis development	32 (%8.4)
There is no definitive conclusion	137 (%36.0)
Other	11 (%2.9)
Preferred probe when measuring probing depth in peri-implant diseases	
Uses plastic periodontal probe because they believe it should be used	177 (%46.5)
Thinks plastic probe should be used, but uses metal periodontal probe because it is not available in the clinic	125 (%32.8)
Does not think plastic probe should be used, therefore uses metal periodontal probe	41 (%10.8)
Uses examination probe because a plastic probe is not available	38 (%10.0)
Threshold probing depth for diagnosing peri-implantitis	
Probing depth of 4 mm or more	177 (%46.5)
Probing depth of 6 mm or more	125 (%32.8)
Probing depth of 8 mm or more	41 (%10.8)
Other	38 (%10.0)
Radiographic bone loss findings suggestive of peri-implantitis	
Progressing bone loss compared to the bone level one year after placing a fixed prosthetic restoration on the implant	222 (58.3%)
Bone loss of 3 mm or more with bleeding on probing, in the absence of initial radiographs or probing depth measurements	171 (44.9%)
1 mm of bone loss in addition to 4-5 mm probing depth six months after placing a fixed prosthetic restoration on the implant	150 (39.4%)
3 mm of bone loss observed on the implant during the placement of the healing abutment in two-stage implants	79 (20.7%)

3. Responses Regarding the Treatment of Peri-implant Diseases

For mechanical debridement, participants primarily preferred plastic instruments (58%) followed by titanium instruments (56.2%) (Table 3). Plaque control was commonly applied to implants with peri-implant mucositis, either always (73.8%) or usually (23.4%), and to implants with peri-implantitis, either always (77.7%) or usually (18.9%). Non-surgical treatment was preferred for peri-implant mucositis either always (37.5%) or usually (44.9%), and for peri-implantitis, either always (42.5%) or usually (37.5%). Oral rinses were preferred either always (42%) or usually (37.5%) for peri-implant mucositis and either always (48.6%) or usually (33.1%) for peri-implantitis. The majority of participants (78%) stated that they would consider non-surgical treatment for peri-implantitis before surgical treatment, as it would facilitate tissue manipulation. For peri-implant mucositis, the most common preferences for local antiseptic/ antibiotic application and systemic antibiotics were "sometimes" (36.7%) and "rarely" (30.4%), respectively, while "sometimes" was the most common response for local antiseptic/antibiotic in peri-implantitis (34.1%). Systemic antibiotics were applied "generally" (28.9%), "sometimes" (27.8%), and "rarely" (2.7%) for peri-implantitis. For peri-implantitis treatment, surgical debridement was preferred either "sometimes" (39.6%) or "generally" (38.1%). Resective and regenerative treatments were occasionally preferred by participants (56.4% and 41.5%, respectively), while implantoplasty was rarely preferred (35.4%). When asked about the use of regenerative treatment during peri-implantitis treatment, most participants stated they would rarely, sometimes, or never apply implantoplasty (34.4%, 23.6%, and 20.2%, respectively). Regarding the effectiveness of current treatments, most participants considered them effective "sometimes" (44.4%) or "mostly" (39.4%) (Table 3).

Table 3. Questions Related to the Treatment of Peri-Implant Diseases (General Distribution)

Questions	Total
Instruments Used for Mechanical Debridement of Peri-Implant Tissues	
Titanium instruments	214 (%56.2)
Carbon fiber instruments	95 (%24.9)
Plastic instruments	221 (%58.0)
Ultrasonic scalers	145 (%38.1)
Stainless steel instruments	28 (%7.3)
Preferred Treatments for Patients with Peri-Implant Mucositis and plaque/calculus	
Plaque Control	
Always	281 (7%3.8)
Generally	89 (%23.4)
Sometimes	9 (%2.4)
Rarely	1 (%0.3)
Never	1 (%0.3)
Nonsurgical treatment	
Always	143 (%37.5)
Generally	171 (%44.9)
Sometimes	49 (%12.9)
Rarely	12 (%3.1)
Never	6 (%1.6)
Mouth rinse	
Always	160 (%42.0)
Generally	143 (%37.5)
Sometimes	52 (%13.6)
Rarely	21 (%5.5)
Never	5 (%1.3)
Local antiseptic/antibiotic	
Always	34 (%8.9)
Generally	78 (%20.5)
Sometimes	140 (%36.7)
Rarely	116 (%30.4)
Never	13 (%3.4)
Systemic antibiotic	
Alway	13 (%3.4)
Generally	57 (%15.0)
Sometimes	95 (%24.9)
Rarely	159 (%41.7)
Never	57 (%15.0)
Other	
Always	5 (%1.3)
Generally	14 (%3.7)
Sometimes	111 (%29.1)
Rarely	145 (%38.1)
Never	106 (%27.8)
Preference for Non-Surgical Treatment Before Performing Surgical Treatment on an Implant with Peri-implantitis	
Considers it ineffective, hence does not consider applying non-surgical treatment	22 (%5.8)
Considers it would facilitate tissue manipulation, hence considers applying non-surgical treatment	297 (%78.0)
Undecided	58 (%15.2)
Other	4 (%1.0)
Preferred Treatment for an Implant with Peri-implantitis	
Plaque control	
Always	296 (%77.7)
Generally	72 (%18.9)
Sometimes	6 (%1.6)
Rarely	4 (%1.0)
Never	3 (%0.8)
Nonsurgical treatment	
Always	162 (%42.5)
Generally	143 (%37.5)
Sometimes	63 (%16.5)
Rarely	8 (%2.1)
Never	5 (%1.3)
Mouth rinse	
Always	185 (%48.6)
Generally	126 (%33.1)
Sometimes	50 (%13.1)
Rarely	14 (%3.7)
Never	6 (%1.6)
Local antiseptic/antibiotic	
Always	56 (%14.7)
Generally	113 (%29.7)
Sometimes	130 (%34.1)
Rarely	70 (%18.4)
Never	12 (%3.1)
Systemic antibiotic	
Always	49 (%12.9)
Generally	110 (%28.9)
Sometimes	94 (%24.7)
Rarely	106 (%27.8)
Never	22 (%5.8)
Surgical treatment	
Always	40 (%10.5)
Generally	145 (%38.1)
Sometimes	151 (%39.6)
Rarely	37 (%9.7)
Never	8 (%2.1)
Resective treatment	
Always	9 (%2.4)
Generall	46 (%12.1)
Sometimes	215 (%56.4)
Rarely	102 (%26.8)
Never	9 (%2.4)
Regenerative treatment	
Always	11 (%2.9)
Generally	70 (%18.4)
Sometimes	158 (%41.5)
Rarely	112 (%29.4)
Never	30 (%7.9)
Implantoplasty	
Always	6 (%1.6)
Generally	41 (%10.8)
Sometimes	128 (%33.6)
Rarely	135 (%35.4)
Never	71 (%18.6)
Other	
Always	2 (%0.5)
Generally	17 (%4.5)
Sometimes	100 (%26.2)
Rarely	125 (%32.8)
Never	137 (%36.0)
Implantoplasty during Regenerative Treatment for Peri-implantitis	
Always	16 (%4.2)
Generally	67 (%17.6)
Sometimes	131 (%34.4)
Rarely	90 (%23.6)
Never	77 (%20.2)
Effectiveness of Current Peri-implantitis Treatment Techniques	
Always effective	2 (%0.5)
Generally effective	150 (%39.4)
Sometimes effective	169 (%44.4)
Rarely effective	55 (%14.4)
Never effective	5 (%1.3)

4. Responses Regarding Risk Factors for Peri-implant Diseases

When asked about the risk factors for peri-implantitis, participants primarily identified a history of periodontitis (94.8%), smoking (93.7%), and diabetes (87.9%) as significant contributors. Regarding factors that could contribute to peri-implantitis development, cement remnants (94.2%) and the implant superstructure (93.4%) were identified as the most significant factors (Table 4).

Table 4. Questions Related to Risk Factors for Peri-Implantitis (General Distribution)

Questions	Total
Known Risk Factors for Peri-Implantitis	
History of periodontitis	361 (%94.8)
Smoking habits	357 (%93.7)
Diabetes	335 (%87.9)
Cancer	140 (%36.7)
Other	59 (%15.5)
Factors That May Contribute To The Development of Peri-Implantitis	
Cement residues	359 (%94.2)
Genetics	208 (%54.6)
Implant superstructure	356 (%93.4)
Occlusal overloa	309 (%81.1)
Other	16 (%4.2)

5. Information Sources and Treatment Preferences Based on Years Since Graduation

The distribution of responses regarding the sources from which participants obtained information about peri-implant diseases showed statistically significant differences based on the years since graduation (p<0.05) (Table 5). Participants who graduated within the last 5 years predominantly obtained information from their university education (88.6%). Those who graduated 5-10 years ago reported using both university education and courses/seminars, with a statistically significant difference compared to other groups (p<0.001). Participants who graduated more than 10 years ago obtained information predominantly from courses/seminars (69.3%), self-study (57.5%), and other sources (11.8%), and these rates were statistically significantly higher than those of the other two groups (p<0.001). Participants who graduated within the last 5 years generally referred patients for peri-implantitis treatment (54.5%), while participants who graduated more than 10 years ago were more likely to perform the treatment themselves, rarely calling specialists (39.4%), with a statistically significant difference (p<0.001) (Table 5).

Table 5. Sources of Information on Peri-Implant Diseases and Preferences for the Treatment of Peri-Implantitis According to Graduation Years

Questions	≤5 years (N=202)	5-10 years 2 (N=52)	≥10 years (N=127)	*p*
Information Source on Peri-Implant Diseases				
Undergraduate education	179 (%88.6)*	40 (%76.9)	38 (%29.9)	< 0.001
Courses and seminars	48 (%23.8)	30 (%57.7)*	88 (%69.3)*	< 0.001
Self-research	68 (%33.7)	19 (%36.5)	73 (%57.5)*	< 0.001
Other	6 (%3.0)	1 (%1.9)	15 (%11.8)*	0.002
Preference for Peri-Implantitis Treatment				
Usually performs it,rarely calls a specialist	35 (%17.3)	12 (%23.1)	50 (%39.4)*	< 0.001
Usually calls a specialist, rarely performs it	47 (%23.3)	16 (%30.8)	33 (%26.0)	
Refers to a specialist	110 (%54.5)*	20 (%38.5)	38 (%29.9)	< 0.001
Other	10 (%5.0)	4 (%7.7)	6 (%4.7)	

* Significant difference from other groups

6. Responses to Questions Regarding Peri-implant Mucosa and Clinical Diagnosis by Years Since Graduation

The distribution of responses regarding the characteristics of peri-implant mucosa did not show statistically significant differences based on years since graduation (p>0.05) (Table 6). Responses regarding the appropriate probe to be used for probing depth measurement during peri-implant disease diagnosis were similar across all groups (p>0.05). There was no statistically significant difference in the responses regarding the probing depth threshold that would suggest peri-implantitis (p>0.05). Responses related to radiographic bone loss and its role in diagnosing peri-implantitis also did not show significant differences based on years since graduation (p>0.05) (Table 6).

Table 6: Responses to Questions Regarding the Characteristics of Peri-Implant Mucosa and the Clinical Diagnosis of Peri-Implant Diseases by Participants According to Years of Graduation

Questions	≤5 years (N=202)	5-10 years 2 (N=52)	≥10 years (N=127)	*p*
Most Important Characteristic of Peri-Implant Mucosa				0.244
Attached peri-implant mucosa	55 (%27.2)	21 (%40.4)	43 (%33.9)	
Keratinized peri-implant mucosa	124 (%61.4)	28 (%53.8)	75 (%59.1)	
Thick peri-implant mucosa in bucco-lingual direction	23 (%11.4)	3 (%5.8)	9 (%7.1)	
Information Regarding the Presence of Keratinized Mucosa Around Implants				0.147
If the amount of keratinized mucosa is less than 2 mm, peri-implantitis will develop	93 (%46.0)	32 (%61.5)	76 (%59.8)	
The absence of keratinized mucosa does not affect the development of peri-implantitis	20 (%9.9)	3 (%5.8)	9 (%7.1)	
There is no definitive result regarding this issue	84 (%41.6)	16 (%30.8)	37 (%29.1)	
Other	5 (%2.5)	1 (%1.9)	5 (%3.9)	
Preferred Probe for Measuring Pocket Depth in Peri-Implant Disease				0.061
Uses plastic periodontal probe because they believe it should be used	100 (%49.5)	22 (%42.3)	55 (%43.3)	
Thinks plastic probe should be used, but uses metal periodontal probe because it is not available in the clinic	71 (%35.1)	19 (%36.5)	35 (%27.6)	
Does not think plastic probe should be used, therefore uses metal periodontal probe	15 (%7.4)	4 (%7.7)	22 (%17.3)	
Uses examination probe because a plastic probe is not available	16 (%7.9)	7 (%13.5)	15 (%11.8)	
Threshold probing depth for diagnosing peri-implantitis				0.061
Probing depth of 4 mm or more	100 (%49.5)	22 (%42.3)	55 (%43.3)	
Probing depth of 6 mm or more	71 (%35.1)	19 (%36.5)	35 (%27.6)	
Probing depth of 8 mm or more	15 (%7.4)	4 (%7.7)	22 (%17.3)	
Other	16 (%7.9)	7 (%13.5)	15 (%11.8)	
Radiographic bone loss findings suggestive of peri-implantitis				
Progressing bone loss compared to the bone level one year after placing a fixed prosthetic restoration on the implant	127 (62.9%)	31 (59.6%)	64 (50.4%)	0.081
Bone loss of 3 mm or more with bleeding on probing, in the absence of initial radiographs or probing depth measurements	67 (33.2%)	29 (55.8%)	75 (59.1%)	
1 mm of bone loss in addition to 4-5 mm probing depth six months after placing a fixed prosthetic restoration on the implant	86 (42.6%)	20 (38.5%)	44 (34.6%)	
3 mm of bone loss observed on the implant during the placement of the healing abutment in two-stage implants	39 (19.3%)	12 (23.1%)	28 (22.0%)	

7. Responses Regarding Peri-implant Disease Treatment by Years Since Graduation

The preferences for mechanical debridement using titanium instruments, plastic instruments, ultrasonic devices, and stainless steel instruments did not differ significantly based on years since graduation (p>0.05). However, carbon fiber instruments were preferred significantly more by those who graduated more than 10 years ago (37.8%) compared to the other groups (p<0.001). For peri-implant mucositis, the frequency of preferences for plaque control, non-surgical treatment, and systemic antibiotics did not differ significantly by graduation year (p>0.05). However, the use of oral rinses was more commonly reported by those who graduated within the last 5 years (18.8%) compared to the other groups (p<0.031). Local antiseptic/antibiotic use was preferred more by participants who graduated more than 10 years ago (p<0.023) (Table 7).

For the preference of non-surgical treatment for peri-implantitis before surgical treatment, there was no significant difference between groups, except for those in the 5-10 year group, who reported a higher preference for not applying non-surgical treatment due to the belief that it would not be effective (p=0.002) (Table 7).

Table 7: Responses of Participants Regarding the Treatment of Peri-Implant Diseases Based on Years Since Graduation

Questions	≤5 years (N=202)	5-10 years 2 (N=52)	≥10 years (N=127)	*p*
Instruments Used for Mechanical Debridement of Peri-Implant Tissues				
Titanium instruments	111 (%55.0)	36 (%69.2)	67 (%52.8)	
Carbon fiber instruments	30 (%14.9)	17 (%32.7)	48 (%37.8)*	< 0.001
Plastic instruments	119 (%58.9)	29 (%55.8)	73 (%57.5)	
Ultrasonic scalers	78 (%38.6)	24 (%46.2)	43 (%33.9)	
Preferred Treatments for Patients with Peri-Implant Mucositis and plaque/calculus				
Plaque Control				0.466
Always	153 (%75.7)	39 (%75.0)	89 (%70.1)	
Generally	41 (%20.3)	13 (%25.0)	35 (%27.6)	
Sometimes	7 (%3.5)	0 (%0.0)	2 (%1.6)	
Rarely	0 (%0.0)	0 (%0.0)	1 (%0.8)	
Never	1 (%0.5)	0 (%0.0)	0 (%0.0)	
Nonsurgical treatment				0.790
Always	75 (%37.1)	23 (%44.2)	45 (%35.4)	
Generally	91 (%45.0)	24 (%46.2)	56 (%44.1)	
Sometimes	26 (%12.9)	5 (%9.6)	18 (%14.2)	
Rarely	7 (%3.5)	0 (%0.0)	5 (%3.9)	
Never	3 (%1.5)	0 (%0.0)	3 (%2.4)	
Mouth rinse				0.031
Always	76 (%37.6)	22 (%42.3)	62 (%48.8)	
Generally	79 (%39.1)	23 (%44.2)	41 (%32.3)	
Sometimes	38 (%18.8)*	2 (%3.8)	12 (%9.4)	
Rarely	7 (%3.5)	4 (%7.7)	10 (%7.9)	
Never	2 (%1.0)	1 (%1.9)	2 (%1.6)	
Local antiseptic/antibiotic				0.023
Always	12 (%5.9)	4 (%7.7)	18 (%14.2)*	
Generally	36 (%17.8)	8 (%15.4)	34 (%26.8)*	
Sometimes	80 (%39.6)	18 (%34.6)	42 (%33.1)	
Rarely	69 (%34.2)	18 (%34.6)	29 (%22.8)	
Never	5 (%2.5)	4 (%7.7)	4 (%3.1)	
Systemic antibiotic				0.501
Alway	5 (%2.5)	3 (%5.8)	5 (%3.9)	
Generally	25 (%12.4)	8 (%15.4)	24 (%18.9)	
Sometimes	46 (%22.8)	13 (%25.0)	36 (%28.3)	
Rarely	93 (%46.0)	21 (%40.4)	45 (%35.4)	
Never	33 (%16.3)	7 (%13.5)	17 (%13.4)	
Preference for Non-Surgical Treatment Before Surgical Treatment in Peri-İmplantitis				0.002
Considers it ineffective. hence does not consider applying non-surgical treatment	5 (%2.5)	8 (%15.4)*	9 (%7.1)	
Considers it would facilitate tissue manipulation, hence considers applying non-surgical treatment	165 (%81.7)	41 (%78.8)	91 (%71.7)	
Undecided	31 (%15.3)	2 (%3.8)	25 (%19.7)	
Other	1 (%0.5)	1 (%1.9)	2 (%1.6)	
Preferred Treatment for An Implant with Peri-Implantitis				
Plaque control				0.481
Always	153 (%75.7)	45 (%86.5)	98 (%77.2)	
Generally	39 (%19.3)	7 (%13.5)	26 (%20.5)	
Sometimes	5 (%2.5)	0 (%0.0)	1 (%0.8)	
Rarely	2 (%1.0)	0 (%0.0)	2 (%1.6)	
Never	3 (%1.5)	0 (%0.0)	0 (%0.0)	
Nonsurgical treatment				0.715
Always	86 (%42.6)	23 (%44.2)	53 (%41.7)	
Generally	80 (%39.6)	20 (%38.5)	43 (%33.9)	
Sometimes	31 (%15.3)	7 (%13.5)	25 (%19.7)	

Rarely	2 (%1.0)	2 (%3.8)	4 (%3.1)	
Never	3 (%1.5)	0 (%0.0)	2 (%1.6)	
Mouth rinse				0.096
Always	88 (%43.6)	22 (%42.3)	75 (%59.1)	
Generally	73 (%36.1)	21 (%40.4)	32 (%25.2)	
Sometimes	32 (%15.8)	6 (%11.5)	12 (%9.4)	
Rarely	5 (%2.5)	3 (%5.8)	6 (%4.7)	
Never	4 (%2.0)	0 (%0.0)	2 (%1.6)	
Local antiseptic/antibiotic				< 0.001
Always	19 (%9.4)	5 (%9.6)	32 (%25.2)*	
Generally	45 (%22.3)	19 (%36.5)	49 (%38.6)*	
Sometimes	89 (%44.1)*	16 (%30.8)	25 (%19.7)	
Rarely	43 (%21.3)	11 (%21.2)	16 (%12.6)	
Never	6 (%3.0)	1 (%1.9)	5 (%3.9)	
Systemic antibiotic				0.021
Always	18 (%8.9)	8 (%15.4)	23 (%18.1)*	
Generally	53 (%26.2)	14 (%26.9)	43 (%33.9)	
Sometimes	46 (%22.8)	16 (%30.8)	32 (%25.2)	
Rarely	69 (%34.2)*	12 (%23.1)	25 (%19.7)	
Never	16 (%7.9)	2 (%3.8)	4 (%3.1)	
Surgical treatment				0.036
Always	12 (%5.9)	5 (%9.6)	23 (%18.1)*	
Generally	79 (%39.1)	19 (%36.5)	47 (%37.0)	
Sometimes	89 (%44.1)	22 (%42.3)	40 (%31.5)	
Rarely	18 (%8.9)	6 (%11.5)	13 (%10.2)	
Never	4 (%2.0)	0 (%0.0)	4 (%3.1)	
Resective treatment				0.004
Always	4 (%2.0)	2 (%3.8)	3 (%2.4)	
Generall	21 (%10.4)	12 (%23.1)*	13 (%10.2)	
Sometimes	115 (%56.9)	24 (%46.2)	76 (%59.8)	
Rarely	61 (%30.2)	14 (%26.9)	27 (%21.3)	
Never	1 (%0.5)	0 (%0.0)	8 (%6.3)	
Regenerative treatment				0.018
Always	3 (%1.5)	2 (%3.8)	6 (%4.7)	
Generally	25 (%12.4)	11 (%21.2)	34 (%26.8)*	
Sometimes	90 (%44.6)	19 (%36.5)	49 (%38.6)	
Rarely	70 (%34.7)*	15 (%28.8)	27 (%21.3)	
Never	14 (%6.9)	5 (%9.6)	11 (%8.7)	
Implantoplasty				0.052
Always	4 (%2.0)	2 (%3.8)	0 (%0.0)	
Generally	20 (%9.9)	9 (%17.3)	12 (%9.4)	
Sometimes	79 (%39.1)	14 (%26.9)	35 (%27.6)	
Rarely	67 (%33.2)	20 (%38.5)	48 (%37.8)	
Never	32 (%15.8)	7 (%13.5)	32 (%25.2)	
Implantoplasty during Regenerative Treatment for Peri-implantitis				0.108
Always	11 (%5.4)	2 (%3.8)	3 (%2.4)	
Generally	35 (%17.3)	11 (%21.2)	21 (%16.5)	
Sometimes	73 (%36.1)	23 (%44.2)	35 (%27.6)	
Rarely	48 (%23.8)	10 (%19.2)	32 (%25.2)	
Never	35 (%17.3)	6 (%11.5)	36 (%28.3)	
Effectiveness of Current Peri-implantitis Treatment Techniques				0.959
Always effective	2 (%1.0)	0 (%0.0)	0 (%0.0)	
Generally effective	82 (%40.6)	20 (%38.5)	48 (%37.8)	
Sometimes effective	87 (%43.1)	23 (%44.2)	59 (%46.5)	
Rarely effective	29 (%14.4)	8 (%15.4)	18 (%14.2)	
Never effective	2 (%1.0)	1 (%1.9)	2 (%1.6)	

* Significant difference from other groups

There were no significant differences in the frequency of use for plaque control, non-surgical debridement, and oral rinses in the treatment of peri-implantitis (p>0.05). However, local antiseptic/antibiotic and systemic antibiotic application preferences were more frequently reported by those who graduated more than 10 years ago compared to those who graduated within the last 5 years (p<0.001, p=0.02). Additionally, surgical debridement was preferred significantly more by those who graduated more than 10 years ago (p=0.036). Resective treatment was most commonly chosen by participants who graduated 5-10 years ago (p=0.004), while regenerative treatment was more frequently chosen by participants who graduated more than 10 years ago (p=0.018). No significant difference was observed in preferences for applying implantoplasty during regenerative treatment for peri-implantitis (p>0.05). Responses regarding the effectiveness of current peri-implantitis treatment techniques showed no significant differences based on years since graduation (p>0.05) (Table 7).

8. Responses Regarding Risk Factors for Peri-implant Diseases by Years Since Graduation

There were no statistically significant differences in the responses regarding risk factors for peri-implantitis or factors contributing to peri-implantitis development based on years since graduation (p>0.05) (Table 8).

Table 8: Responses of Participants Regarding Risk Factors for Peri-Implant Diseases Based on Years Since Graduation

Questions	≤5 years (N=202)	5-10 years 2 (N=52)	≥10 years (N=127)	*p*
Known Risk Factors for Peri-Implantitis				
History of periodontitis	193 (%95.5)	48 (%92.3)	120 (%94.5)	0.638
Smoking habits	191 (%94.6)	48 (%92.3)	118 (%92.9)	0.758
Diabetes	177 (%87.6)	47 (%90.4)	111 (%87.4)	0.841
Cancer	77 (%38.1)	21 (%40.4)	42 (%33.1)	0.549
Other	24 (%11.9)	9 (%17.3)	26 (%20.5)	0.103
Factors That May Contribute To The Development of Peri-İmplantitis				
Cement residues	186 (%92.1)	50 (%96.2)	123 (%96.9)	0.159
Genetics	114 (%56.4)	31 (%59.6)	63 (%49.6)	0.353
Implant superstructure	185 (%91.6)	49 (%94.2)	122 (%96.1)	0.271
Occlusal overloa	164 (%81.2)	38 (%73.1)	107 (%84.3)	0.222
Other	7 (%3.5)	1 (%1.9)	8 (%6.3)	0.312

DISCUSSION

With the increasing use of dental implants, the prevalence of peri-implant diseases has also risen, prompting research to focus on this issue.[14] The rise in the frequency of peri-implant diseases has made it crucial for dental practitioners to possess adequate knowledge in this area. Therefore, the aim of our survey was to evaluate the diagnostic and treatment approaches to peri-implant diseases among general dentists who do not have specialized or doctoral qualifications.

When participants were asked about the sources of information they relied on regarding peri-implant diseases, those who graduated in the last five years reported obtaining most of their knowledge from university education (88.6%), while those who graduated 5-10 years ago primarily referred to undergraduate education, but also relied on courses and seminars. Participants who had graduated more than 10 years ago reported that only 29.9% of their knowledge came from undergraduate education, while 69.3% acquired it through courses and seminars, and 57.5% through self-research. Given the timing of changes in educational programs, it is likely that older graduates sought to address their knowledge gaps by attending courses and seminars or conducting independent research. The modifications in the undergraduate curriculum over the years may have contributed to this trend. There were no significant differences between the groups regarding the expected characteristics of peri-implant mucosa, the amount of keratinized mucosa, the probing depth threshold for peri-implantitis, or the preferred instruments for probing depth measurements. This suggests that general dentists who had insufficient information during their undergraduate education were able to acquire accurate knowledge through post-graduate education. In our study, bleeding on probing was not included as a separate question because, although it is important for the diagnosis of peri-implantitis, it can also be observed in peri-implant mucositis, making it non-specific. Therefore, bleeding on probing could be asked along with other diagnostic features in future survey studies to gather more detailed information on the subject.

Participants who graduated in the last five years generally reported referring patients for peri-implantitis treatment (54.5%), whereas those with more than 10 years of experience indicated that they mostly treated the patients themselves (39.4%), with a lower rate of patient referral (29.9%). In the DUCEP program, peri-implantitis is taught only at the diagnostic and preventive level, and it is recommended that patients be referred to specialists for treatment. Peri-implant diseases can be complex to treat, and professional experience is important in this regard. Therefore, it is possible that recently graduated participants are more likely to refer patients for treatment due to limited experience in managing peri-implant diseases.

In our study, 38.1% of participants reported using ultrasonic devices for mechanical debridement, which is lower than in similar studies.[15-18] This difference may be due to the fact that the question in our survey did not emphasize the selection of appropriate ultrasonic tips for implants. The use of stainless steel instruments was also low (7.3%) compared to similar studies.[15-17] The preference for titanium instruments was found to be 56.2%, which is higher than in similar studies.[16,17] Both undergraduate education and continuing education in courses and seminars stress that instruments designed for teeth are not suitable for implants and that special tips and instruments should be used for implants. Therefore, titanium instruments are preferred more frequently than ultrasonic and stainless-steel instruments, likely due to the education provided in these settings. In a study by Mattheos et al.[16], the use of plastic instruments was 65.6% in the UK and 39.7% in Australia. In the study by Papathanasiou et al.[17], periodontists preferred plastic instruments 42.5% of the time. In our survey, the preference for plastic instruments was 58%. These surveys targeted specialists, whereas our survey was conducted among general dentists without specialization or doctoral qualifications, which may account for the differences in results.

The importance of plaque control in the treatment of peri-implant diseases is well established.[19,20] In our survey, the responses regarding plaque control in treatment were consistent with the literature and similar studies.[15-17] In a study by Khan et al.[15], 88.9% of participants always preferred plaque control. In our study, plaque control was consistently used by participants across all groups in the treatment of peri-implant mucositis. In our study, the most common frequencies for non-surgical debridement in peri-implant mucositis treatment were "always" (37.5%) and "usually" (44.9%). These results are consistent with the findings of Papathanasiou et al. (always 49.1%, usually 32.6%)[17]. The use of mouth rinses was a commonly used method in the treatment of both peri-implant mucositis and peri-implantitis, which aligns with similar studies.[15-17] In our study, the use of local antibiotics/antiseptics in peri-implant mucositis treatment was in line with the findings of Papathanasiou et al.[17], although in the study by Mattheos et al.[16], most clinicians reported that they never preferred local antibiotics. In our study, the frequency of local antibiotic/antiseptic use in peri-implant mucositis and peri-implantitis was similar. Similar findings were observed in the study by Papathanasiou et al.[17], while in two other studies[16,18], the preference for local antibiotics was lower. These differences in local antiseptic/antibiotic preferences may be due to variations in pharmaceutical markets between countries.

The frequency of systemic antibiotic use in peri-implantitis treatment was lower in our study compared to similar studies.[15,16,18] Participants with over 10 years of experience reported a higher frequency of systemic antibiotic use in peri-implantitis, while younger participants preferred it less. The growing awareness of antibiotic resistance in recent years may have contributed to this difference.

Participants in our survey (78%) reported considering non-surgical treatments before opting for surgical interventions in peri-implantitis, as these treatments facilitate tissue manipulation in more advanced cases. A higher proportion of participants who graduated within the last 5 years indicated this preference. Longer-graduated participants, most of whom work in the private sector, may have been influenced by the need for quicker solutions to patient problems in private practice. The most common answer for surgical debridement was "sometimes" (39.6%). In the study by Khan et al.[15], the most common response for surgical debridement was "usually" (51%). The lower frequency of surgical debridement in our study may be attributed to the fact that our participants were general dentists rather than specialists. While peri-implantitis is taught theoretically in undergraduate education, it is practiced in specialist training programs. When questioned about the preference for surgical debridement in peri-implantitis treatment, there was no significant difference between the groups, with similar responses of "sometimes," "usually," and "rarely" across all groups. However, dentists with more than 10 years of experience significantly preferred the "always" option compared to other groups. This finding may reflect the influence of their clinical experience and expertise.

Regarding the choice between resective or regenerative procedures for peri-implantitis, 56.4% of participants stated they would sometimes choose a resective procedure, while 41.5% would sometimes choose a regenerative approach. In the study by Khan et al.[15], 44.2% of participants generally preferred resective treatment, while 39.5% preferred regenerative treatment.

In the study by Papathanasiou et al.[17], the most frequent response was "sometimes" (45.5%). This suggests that regenerative procedures, which are more complex and require more experience, may be less frequently chosen by younger or less experienced dentists. In a study by Schmidlin et al.[18], non-specialist dentists preferred regenerative procedures (56%) over resective procedures (47%). In the same study, specialists preferred regenerative treatment (78.8%) over resective treatment (68.4%). Similarly, in the survey by Papathanasiou et al.[17], regenerative procedures were preferred more frequently (always 9.4%, usually 30.2%) compared to resective procedures (always 3.5%, usually 22.7%). The clinical experience, training, specialization, and the cost of biomaterials used may all influence these results.

There were limitations in the present study. The voluntary nature of survey participation may have led to a higher response rate from dentists interested in peri-implant diseases, potentially affecting the results. Additionally, the fact that the survey was distributed through the researchers' social media accounts may have contributed to a younger age distribution among participants, which could have influenced the responses.

CONCLUSION

Recent graduates have a relatively high level of knowledge about peri-implant diseases and their treatments. Older graduates, who did not acquire sufficient knowledge during their undergraduate education, have made efforts to acquire information through courses, seminars, and self-research. Therefore, more comprehensive education programs, courses, and seminars should be organized for older graduates. Further research into dentists' attitudes towards the diagnosis and treatment of peri-implant diseases will help identify gaps in knowledge and enable the development of additional educational initiatives. Future studies with a more balanced participant distribution and larger sample sizes will provide further insights into this topic.

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Investigation of Color and Microhardness Changes in Direct, Indirect, and 3D-Printed Composites

Direkt, İndirekt ve Üç Boyutlu Baskı Kompozitlerin Renk ve Mikrosertlik Değişimlerinin İncelenmesi

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ABSTRACT

INTRODUCTION: The aim of this study was to determine the surface hardness and color changes of resin composites produced for direct, indirect, and 3D printing applications.

MATERIAL and METHODS: Forty-five samples with a diameter of 9 mm and a thickness of 3 mm were prepared. After polymerization, the samples underwent ultrasonic cleaning, polishing, and coloring procedures. Microhardness measurements were taken using a Vickers microhardness device, and color change parameters were determined using a spectrophotometer. The data were statistically evaluated using ANOVA for repeated measurements.

RESULTS: Significant differences were found in microhardness measurements among the three different composite resin groups after initial, ultrasonic cleaning, polishing, and coloring procedures ($p < 0.05$). However, there was no significant difference in microhardness measurements between the initial and ultrasonic cleaning stages ($p > 0.05$). Microhardness values differed significantly after polishing and coloring ($p < 0.05$). Orange juice did not cause a significant color change (ΔE) in any of the restorative materials ($p > 0.05$), while significant color change (ΔE) was found in samples exposed to coffee after orange juice ($p < 0.05$).

CONCLUSION: The color and microhardness of all used composites were affected by polishing and coloring procedures, with varying effects observed for each material.

Keywords: *Microhardness, Color change, Nano-hybrid composite, Universal resin composite, 3D printing*

ÖZ

GİRİŞ: Direkt, indirekt ve 3 boyutlu baskı için üretilmiş likit rezin kompozitlerin yüzey sertliği ve renk değişiminin tespiti amaçlandı.

YÖNTEM ve GEREÇLER: 9 mm çap ve 3 mm kalınlıkta hazırlanan 45 örneğin polimerizasyonunu takiben örneklerin ultrasonik yıkama, polisaj ve renklendirme prosedürü sonrası mikrosertlik ölçümleri alındı. Mikrosertlik Vickers mikrosertlik cihazıyla renk değişimi parametresi ise spektrofotometre kullanılarak tespit edildi. Elde edilen veriler istatistiksel olarak tekrarlayan ölçümler için ANOVA, Pearson korelasyon analizi ile değerlendirildi.

BULGULAR: Üç farklı kompozit rezin grubunun başlangıç, ultrasonik yıkama, polisaj ve renklendirme prosedürü sonrası alınan mikrosertlik ölçümleri arasında anlamlı fark bulundu ($p <0,05$). Bu üç restorasyon materyalinin başlangıç ve ultrasonik yıkama sonrası mikrosertlik ölçümleri arasında anlamlı fark bulunmadı ($p >0,05$). Ancak polisaj ve renklendirme sonrası mikrosertlik değerleri birbirlerinden farklıydı ($p <0,05$). Restorasyon materyallerinde ortaya çıkan renk değişim miktarları ve mikrosertlik ölçümleri arasında korelasyon bulunmadı. Portakal suyunun tüm restorasyon materyallerinde anlamlı bir renk değişimine (ΔE) neden olmadığı ($p >0,05$), kahve ve portakal suyu sonrasında kahve uygulanan örneklerde anlamlı renk değişimi (ΔE) bulundu ($p <0,05$).

SONUÇ: Kullanılan tüm kompozitlerin renginin ve mikrosertliğinin polisaj ve renklendirme prosedüründen etkilendiği ve bu etkinin her materyalde farklı olduğu izlendi.

Anahtar Kelimeler: *Mikrosertlik, renk değişimi, nano hibrit kompozit, üniversal rezin kompozit, üç boyutlu baskı*

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INTRODUCTION

Dental resin composites, first developed by Rafael Bowen by combining dimethacrylates (epoxy resin and methacrylic acid) with a certain proportion of silanized quartz, are the most widely used aesthetic restorative materials.[1] The first produced and chemically polymerized resin composites were recommended for use in class III, IV, V cavities. A significant development for dental composites occurred in the 1970s with the development of light-polymerized resins, and many initial disadvantages were overcome with continuous research and developing technology.[2] Thus, resin composites, whose indications were initially limited to small and medium-sized cavities, can now be used in large and deep cavities of the posterior region thanks to the use of polymerization systems that enable the use of different techniques during the construction phase, structural and chemical changes in resin and inorganic particles.

In the past, the biggest obstacle to the use of resin composites in deep and large cavities was the shrinkage that occurs during their polymerization and the need to improve the mechanical properties of the material.[3] For this reason, the first generation of indirect resin composites was introduced by Touati and Mormann in the 1980s for use in posterior inlay and onlay restorations.[4] In this way, it has been possible to obtain long-lasting, durable, and aesthetic restorations with reduced polymerization shrinkage, which preserve the remaining tooth structure in teeth with high material loss. Despite their advantages, the use of these materials requires additional procedures and time, as well as an extra financial burden on the patient. Consequently, advancements in technology aim to streamline the application process for indirect inlay and onlay procedures, thereby minimizing both time and financial burdens on patients. For this purpose, traditional impression and production methods, which are the application procedures for indirect resin composites, have been replaced by computer-based "Computer Aided Design and Manufacturing" (CAD/CAM) design and production methods with the introduction of various products based on new technologies. Desktop intraoral scanners are needed for CAD/CAM, which means computer-aided design and computer-aided manufacturing at the patients' chairside. This facilitates the acquisition of more precise data and the design of virtual restorations using CAD software, which is then transferred to a manufacturing process.[5] Computer-aided manufacturing can be performed by subtractive methods using a milling unit, as well as by additive method, that is, three-dimensional printing, which has recently been introduced to the market. The first three-dimensional printers that produced with three-dimensional printing technology were able to produce using "Selective Laser Sintering" (SLS) and "Fused Deposition Modelling" (FDM) methods.[6] Over time, three-dimensional printers have evolved to enable the production of materials that are more resistant to the oral environment, long-lasting and aesthetic at the same time.[6] The first three-dimensional printers used plastic or metal as raw materials. Advancements in three-dimensional printing technology have led to the creation of printers capable of integrating epoxy resin-based composite-ceramic hybrid materials, which are polymerized using heat and light. Examples of systems that use a liquid photopolymer "hybrid resin" that can be polymerized with ultraviolet (UV) light include Digital Light Projection [Digital Light Processing (DLP)] and Stereolithography (SLA) printers. With the high accuracy and resolution of these systems, biocompatible restorations can be produced in a short time and in a way that is attractive to both patients and clinicians.[7]

A good and reliable aesthetic restorative material, whether produced by the direct or indirect method, should be able to mimic the appearance of natural teeth in addition to its strong structural properties. This is related to the color matching and color stability of the material. An esthetic restorative material with advanced chemical and mechanical properties should also be resistant to erosive conditions in the mouth. Dental erosion is one of the most common pathologies in today's lifestyle where acidic foods and beverages are frequently consumed.[8] There are many studies in the literature that reveal the link between dental erosion and acidic foods and beverages. In addition to erosive foods and beverages, coffee is one of the beverages that almost everyone consumes on a daily basis in today's lifestyle. As a coloring agent, coffee consumption is second after water consumption, with an annual consumption of more than 500 billion cups by people all over the world.[9,10] Not only the chewing forces in the mouth, but also erosive and coloring agents from food and beverages are a threat to a dental restorative material. Therefore, this study aimed to see how the surface microhardness and color stability of dental resin composites produced by different techniques are affected under erosive and staining threats. For this purpose, the null hypothesis of the study is that the surface microhardness and color stability of aesthetic dental resin composites produced by different techniques are not affected by orange juice and coffee consumption.

MATERIALS and METHODS

1. Preparation of Samples

In this study, 3 different types of resin composite materials were used (Table 1). Group A was a direct universal resin composite, while group B was an indirect nano-hybrid resin composite. Group C was a liquid resin composite (3D composite) produced for 3D printing. Resin composites in all groups were used in shade A2. The flowchart of the study is shown in Figure 1. A total of 45 samples were prepared, 15 in each group.

Table 1. Materials, properties, ingredients and manufacturing companies.

	Material Type	Material Form	Brand Name	Lot Number, Shade	Ingredients	Manufacturer
Group A	Direct Resin Composite	Universal Composite	3M Filtek Supreme Ultra Universal Restorative	9406537, A2	BIS-GMA, BIS-EMA6, UDMA, PEGDMA, Triethylene Glycol Dimethacrylate, Phenyl bis (2,4,6-trimethylbenzoyl), Phosphine Oxide, Silanized Ceramic, Zirconia Silanized Silica, Filler Volume: %60-80 +1-5	3M Canada Company
Group B	Indirect Resin Composite	Nano Hybride Composite	Gradia Plus Heavy Body Dentin	2302101,H B-DA2	%1–5: BIS-GMA, %5–10: TEGDMA % 1-5 UDMA:, Ceramic-filled inorganic fillers (%71 by weight), Prepolymerized fillers (%6 by weight), Filler volume %71+%6	GC Europe, Leuven, Belgium
Group C	Liquid Resin, (for 3D Printing)	Liquid Resin	Varseo Smile Crown Plus	A2 Dentin	4′-Isopropylidenediphenol, Ethoxylated and 2-Methylprop-2-enoic Acid, Silanized Dental Glass, Methyl Benzoylformate, Diphenyl (2,4,6-trimethylbenzoyl) Phosphine Oxide, Inorganic Fillers: 30-50% by weight (particle size 0,7 µm)	BEGO, Bremen Germany

1.1 Preparation of Resin Composite Samples in Groups A and B

The resin composite samples were placed in silicone molds with an inner diameter of 9 mm and a height of 3 mm with a 2 mm layering technique. For this purpose, a setup including a transparent celluloid strip and a 1 mm thick slide was used under and over the silicone mold. The distance between the samples and the light source was standardized by using a glass slide (1 mm thickness). The placed resin composite layers were polymerized over the slide with an LED light device Blue Phase (Ivoclar/Vivadent, Liechtenstein) with a light intensity of 1200 mW/cm^2 for 20 seconds in soft start program mode according to the manufacturer's recommendation. Unlike group A, resin composite samples in group B were cured in Autoflash (Bego, Germany) for 1500 pulses x 2 times following polymerization with an LED light unit. Then, the samples in both A and B groups were stored in distilled water at 37°C for 7 days to ensure post polymerization.

1.2 Preparation of Liquid Resin Composite Samples Used with Three Dimensional Printing Method

Group C samples were designed in a CAD (Computer Aided Design) program called Autodesk Fusion 360 (Autodesk Inc., USA) with an inner diameter of 9 mm and a height of 3 mm. The samples designed in this program were made ready for printing using Bego Cam Creator (Bego, Germany), a slicing software. The samples were then produced on a compact DLP (Digital Light Processing) 3D printer Varseo xs (Bego, Germany) using Varseo Crown Plus Dentin, a permanent liquid resin. Then, they were cured in autoflash (Bego, Germany) at 1500 pulses x 2 times. Subsequently, the samples were ultrasonically irrigated.

1.3 Ultrasonic Irrigation of Samples

Since the 3D resin composite produced should be subjected to ultrasonic irrigation as a production step, all samples used in the study were irrigated with isopropyl alcohol in ProWash S (Sprintray, USA) for 15 minutes to create standardization. All samples were then kept in an incubator at 37 °C for 7 days, moistened with distilled water.

1.4 Polishing of Samples

All groups were polished using the Shofu Super-Snap Rainbow Technique polishing kit (Shofu, Japan) without water cooling at 15,000 rpm for 30 seconds.

2. Microhardness measurement

In this research, all samples were kept at 37 °C for 7 days and the microhardness measurements were carried out at pre-polishing, post-ultrasonic irrigation, post-polishing, pre-staining and post-staining stages for samples in groups A and B, and at post-ultrasonic irrigation, post-polishing, pre-staining and post-staining stages for those in group C (Figure 1). Measurements were performed 3 times at 2 mm intervals along the diameter of the sample. A Shimadzu MCT-510 (Shimadzu, Japan) microhardness tester was used for the microhardness measurements. For the measurement, a Vickers diamond tip was applied to the material surfaces for 15 seconds with 100 g load. The "trace" obtained was then imaged with the help of a digital camera M 1192 (Carl Zeiss Jena, Germany) and transferred to the computer connected to the device. These images were measured and recorded as Vickers Hardness Values (VHV) using the "Kameram" program.

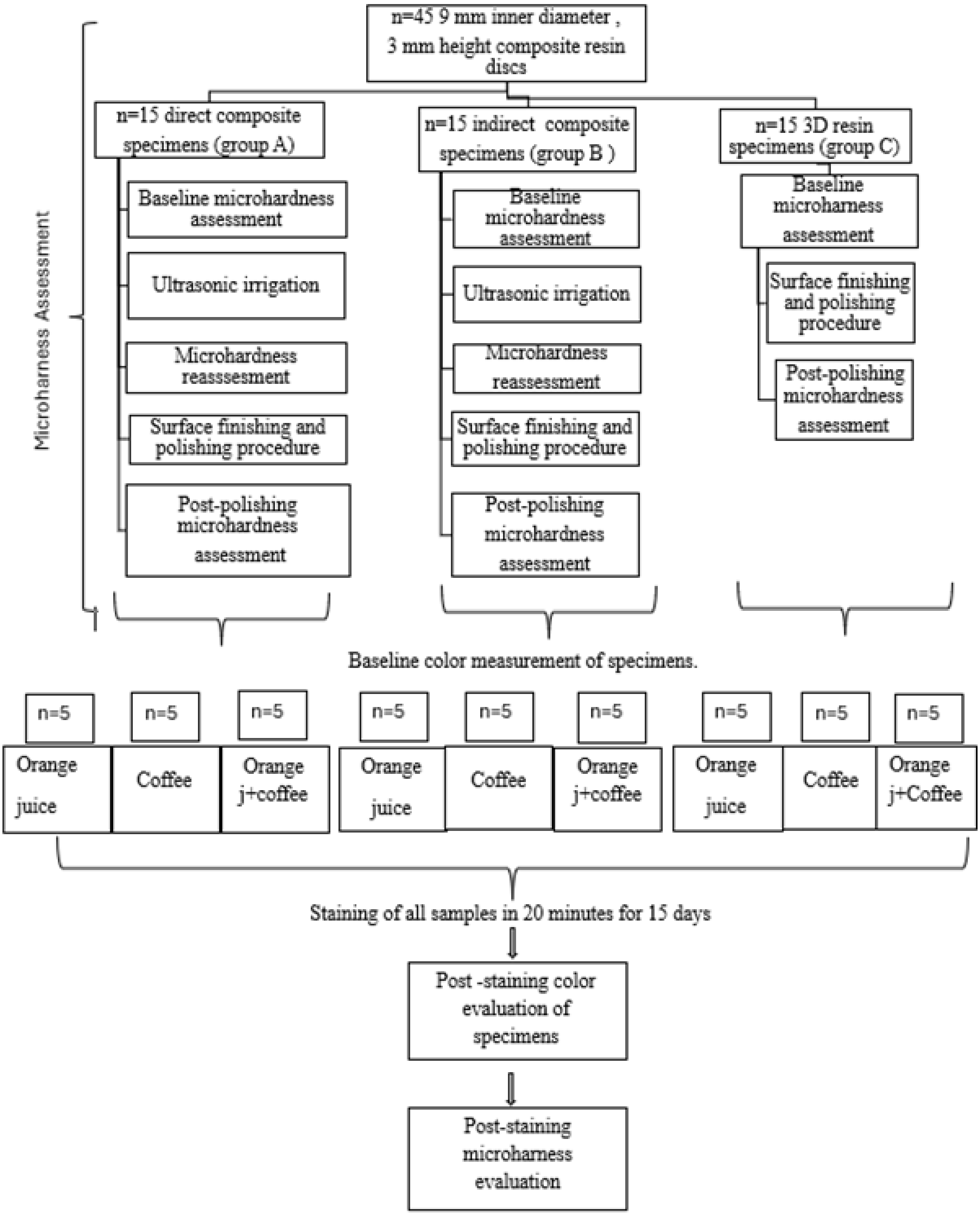

Figure 1. Flow Chart

3. Staining of Samples

A total of 45 samples were divided into groups of 5 and exposed to coffee and/or orange juice for 20 min per day for 15 days. The samples in group A1 were exposed only to orange juice (Cappy Coca-Cola Company, Istanbul, Turkey, pH 3.75), those in group A2 were exposed only to coffee, and those in group A3 were first exposed to orange juice for 20 min, then to coffee for 20 min after irrigating with distilled water. Similar solutions of 200 ml were prepared for groups B and C. The coffee solution was prepared by mixing 2 g of soluble coffee (Nescafe Classic, Nestle, Bursa, Turkey, pH 4.73) in 200 ml of hot water. A new solution was used every day. Distilled water was then used as a storage medium.

4. Color measurement

Initial color measurements of all samples were conducted after polishing, while final measurements were taken subsequent to staining. The color measurements of the samples were performed under D65 standard lighting conditions corresponding to daylight and the device was calibrated before each measurement. Measurements were performed on a standard white background (L=91.2, c=1.5, h=113.2) using VITA Easyshade® V (Vita Zahnfabrik, USA). The device was calibrated before each measurement and the average CIE L* c* h* value obtained from 3 measurements taken from 3 different points of the disc-shaped material was calculated using the CIEDE 2000 (Picture 1). ΔE values were calculated by using the formula. ΔL', ΔC' and ΔH' in the formula define the differences in lightness, chroma and hue between 2 different measurements. lightness (SL), color (SC), and tone (SH) weighting functions for color intensity and hue. RT is the turnover function describing the amount of interaction between color intensity and hue differences in the blue area in the CIE L*a*b color system. KL, KC and KH are parametric factors evaluated for brightness, color intensity and hue. In this study, KL, KC and KH were considered as "1".

5. Statistical analyses

Statistical analyses were performed using the SPSS program (version 27, IBM, Armonk, USA). The Kolmogorov-Smirnov test was used for normal distribution and Levene's test was used for homogeneity of variances. Comparison of the surface microhardness of different composites was tested by one way ANOVA on the mean data. In addition, the mean microhardness values obtained after 4 different steps (repeated measurements) were evaluated with two way ANOVA and post-hoc Tukey test by creating a generalized linear model. The correlation between microhardness data and Delta E data obtained as a result of staining was examined by Pearson correlation analysis. The statistical significance level was taken as "p<0.05". Power analysis G-power (version 3.0.1, University of Düsseldorf, Germany) was performed to calculate the sample size in the study with repeated measurements, and it was calculated that the study could be performed with a total of 27 samples with a minimum sample size of 3 for each group, an effect value (f) of 1.000173, a critical F value of 2.510157 and a power value of 98.537%. Based on these data, the study was completed with a total of 45 samples with a minimum number of 5 samples in each group with the same effect value and a critical F value of 2.2085181 and a power of 99.999%.

RESULTS

I. Microhardness

According to ANOVA for Repeated Measures, the microhardness measurements of the 3 different resin composite groups taken at baseline, after ultrasonic irrigation, after polishing and after the staining procedure indicated significant differences between the indirect, direct and 3D resin composite groups (p <0.05). However, there was no significant difference between the initial and post-ultrasonic irrigation microhardness measurements of the three different restoration materials used (p >0.05). However, the initial measurements and the microhardness values after polishing and staining were also different from each other (p <0.05). According to pairwise comparisons, these differences were observed for the direct resin composite group between coffee and orange juice in the staining procedure, which showed that orange juice reduced the microhardness more than coffee (p <0.05). Exposure to orange juice followed by coffee did not cause any additional change in microhardness (p >0.05). The microhardness changes of all three restoration materials compared to baseline were different for the three different treatments included in the staining procedure (orange juice, coffee, orange juice + coffee), (p <0.05). The most affected restoration material was the indirect resin composite for the orange juice and coffee groups and the 3D resin composite for the orange juice + coffee group (Figure 2). The percentage change of microhardness values caused by the staining procedure in the restoration materials is presented in (Table 3).

$$\Delta E_{00} = \left[\left(\frac{\Delta L'}{K_L S_L} \right)^2 + \left(\frac{\Delta C'}{K_C S_C} \right)^2 + \left(\frac{\Delta H'}{K_H S_H} \right)^2 + R_T \left(\frac{\Delta C'}{K_C S_C} \right) \left(\frac{\Delta H'}{K_H S_H} \right) \right]^{1/2}$$

Picture 1. CIEDE 2000 (DE00) formula

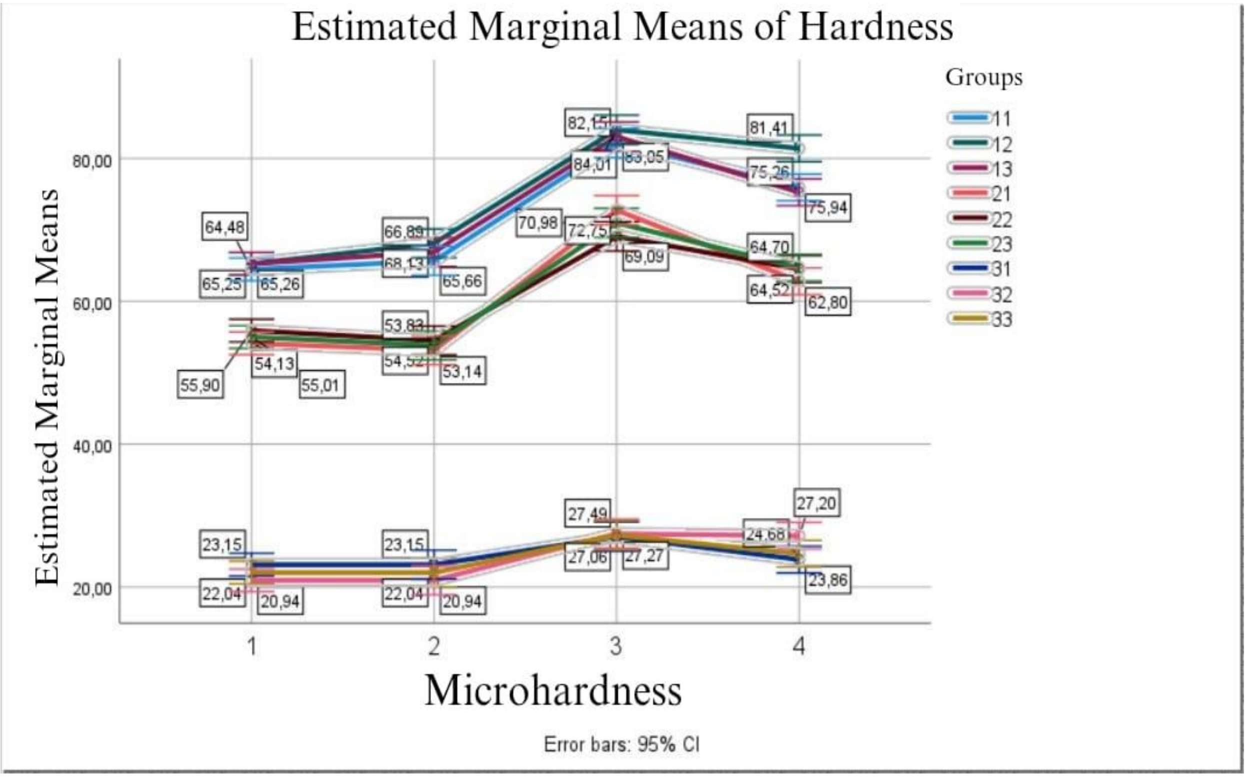

Figure 2. Microhardness values represent; Number 1 before the procedure, number 2 after ultrasonic irrigation, number 3 after polishing, number 4 after process. Groups: Group number 11 direct composite with orange juice, group number 12 direct composite with coffee, group number 13 direct composite with orange juice + coffee, group number 21 indirect composite with orange juice, group number 22 indirect composite with coffee, group number 23 indirect composite with orange juice + coffee, group number 31 3D resin with orange juice, group number 32 3D resin with coffee, group number 33 3D resin with orange juice + coffee

Table 2. Initial L-C-H Values (L mean, C mean, H mean), values after the staining procedure (L mean 2,C mean 2, H mean 2), values of shade change (ΔE**).**

	L (mean)	C (mean)	H (mean)	L (mean 2)	C (mean 2)	H (mean 2)	ΔE
Universal Composite							
Orange Juice	78,44	24,72	92,76	78,9	24,34	92,98	1,204
Coffee	77,56	23,5	93,53	73,74	27,33	90,54	6,21
Orange Juice and Coffee	78,22	24,42	93,06	73,88	26,90	89,68	6,19
Indirect Composite							
Orange Juice	80,14	41,68	87,34	80,6	42,3	87,74	0,924
Coffee	79,98	42,36	87,32	74,15	45,36	84,82	7,05
Orange Juice and Coffee	79,9	41,76	87,42	76,14	43,48	85,74	4,604
3D Liquid Resin							
Orange Juice	78,38	25,6	89,06	78	26,28	89,78	1.188
Coffee	78,66	25,44	89,1	74,12	27,88	88,52	5,278
Orange Juice and Coffee	78,48	25,98	89,1	73,7	28,02	87,88	5,518

II. Color change ΔE values

When the amount of color change in the restoration materials after the staining procedure was compared, it was observed that orange juice did not cause a significant color change (ΔE) in all restoration materials ($p > 0.05$), but there was a significant color change (ΔE) in all coffee-treated samples and orange juice+coffee samples ($p < 0.05$). Accordingly, the highest color change after coffee application was observed in indirect resin composite, followed by direct resin composite and 3D resin composite, respectively. In coffee application after orange juice, the highest color change was observed in direct resin composite, followed by 3D resin and indirect resin composite, respectively (Table 2).

Table 3. Microhardness changes before and after staining procedure.

	INITIAL	ULTRASONIC CLEANING	POLISHING	STAINING	CHANGE (%)
Universal Composite					
Orange Juice	64,47 ±3,12	65,66 ±4,10	82,15 ±1,16	75,94 ±1,91	7,55%
Coffee	65,25 ± 2,63	68,12 ±2,90	84,00 ± 3,35	81,40 ± 1,81	3,09%
Orange Juice and Coffee	65,26 ± 0,56	66,89 ±0,01	83,05 ±0,01	75,25 ±0,94	9,38%
Indirect Composite					
Orange Juice	54,12 ± 1,14	53,14 ±2,61	72,75 ±1,63	62,80 ±2,0	13,67%
Coffee	55,90 ± 0,47	54,52 ±1,76	69,08 ±4,95	64,51 ±3,69	6,61%
Orange Juice and Coffee	55,01 ±0,01	53,83 ±0,01	70,98 ±0,01	64,70 ±3,36	8,84%
3D Liquid Resin					
Orange Juice	23,15 ± 2,58	23,15 ± 2,58	27,06 ±1,71	23,85 ±0,84	11,85%
Coffee	20,94 ± 1,54	20,94 ±1,54	27,48 ±1,75	27,20 ±0,73	1,04%
Orange Juice and Coffee	22,04 ± 0,01	22,04 ±0,01	27,27 ±0,01	24,67 ±1,55	9,51%

DISCUSSION

This study investigated the surface hardness and color change parameters of direct, indirect, and 3D resin composites. The null hypothesis was rejected, as the polishing and staining procedures significantly influenced the color and microhardness of all composites, with variations observed among the materials. The surface hardness of a restorative material is an important factor related to the wear of the material, affecting its clinical success and providing resistance to plaque formation.[11] The Vickers microhardness apparatus was employed for microhardness assessment in this study owing to its benefits, including high precision, resistance to deformation of the diamond tip when utilized appropriately, prolonged usability, a single tip sufficing for all materials, complete adaptability to both soft and hard surfaces, and accurate measurement.[12] Visual assessment of the color stability of dental resin composite is often misleading because it is known that the human eye is closely related to the light source, gingival color, distance of the colored object from the eye, environmental factors, and the experience of the clinician trying to determine the color.[13] For precise, reliable and reproducible results, the use of a spectrophotometer was preferred in this study. The surface microhardness of the three different groups of resin composites used in this study was initially different from each other. This difference is thought to be due to the difference in the chemical properties of the materials and the type, size and proportion of inorganic filler. Indeed, Szalewski et al. concluded that the changes in the materials were related to the filler ratio and size in their study in which they examined the flexural strength and surface microhardness of these materials following staining and erosive procedures applied to different groups of nanohybrid and microhybrid resin composites.[14] The microhardness values of all resin composites examined in this study exhibited alterations from the initial values, irrespective of the staining procedure employed. Barve et al. also used staining and erosive beverages on two different types of nanofill and micro-hybrid composites noting a variation in microhardness across all experimental groups.[15] When the results of the aforementioned study and the results of this study are evaluated together, it is possible to say that the surface hardness of all resin composites subjected to staining and/or erosive procedures changes regardless of the composite type. The change in the microhardness of the material after the staining procedure is explained by the degradation of the silica matrix after the use of colorant and/or erosive beverage and the subsequent leakage of the colorant content between the organic matrix and the filler phase.[15] Yanıkoğlu et al. [16] found a significant difference between the surface hardness of the samples kept in a humid environment and the samples kept dry and found a decrease in the surface microhardness values of the samples kept in a humid environment as a result of water absorption and matrix degradation. In summary, the surface microhardness values of resin composites are related to the water absorption of the material and this change is reported to occur within the first 7 days.[17] The indirect resin composite exhibited the most significant alteration in microhardness among the material groups, attributed to its formation of prepolymerized inorganic filler and the hydrophilic TEGDMA (Triethylene glycol dimethacrylate) monomer within the organic matrix, making the material susceptible to degradation from erosive beverages. The polymerization rate of liquid resins produced for 3D printing is lower than that of conventional dental resin composites and there are more residual monomers on the surface of these composites after curing, which cause deterioration in the surface integrity of the material and softening on the surface.[18,19] As a matter of fact, in this study, the microhardness values of the 3D resin composite were found to be low compared to other composites. In the literature, phosphine oxides, which are frequently used as photoinitiators, are blamed for the low curing depth of liquid resin composites produced for 3D printing and the resulting excessive amount of residual monomer.[18] Ultrasonic irrigation is a necessity in the production stage of three-dimensional liquid resin composites. For this reason, the other composites used in this study were subjected to ultrasonic irrigation just like the 3D composites and their microhardness was measured. It was determined that polishing was the process that caused the microhardness change in all composite types. Similarly, there are results in the literature that the polishing process for resin composites increases the microhardness of the materials.[20,21] However, the material with the least microhardness difference caused by polishing is the 3D resin composite, which can be associated with the low inorganic content of the material. The increase in microhardness of the material post-polishing results from the elimination of the oxygen inhibition layer, which adversely affects the material's mechanical properties due to high resin content. [20] In the study, the microhardness values of all resin composite groups treated with orange juice showed a greater decrease compared to the groups treated with coffee. This difference may not only be related to the pH of orange juice, but also to the amount of titratable acid and chelation quality. The chelating agents in orange juice may be responsible for this change by interacting with the inorganic particles in the resin composite.[22,23] Another objective of this in vitro study was to determine the color stability of the materials following various staining procedures. When the amount of color change was compared, no statistically significant ΔE change was detected in all groups treated with orange juice, but the ΔE change was significant in all groups treated with coffee after orange juice+coffee. There was no correlation between the microhardness change caused by orange juice and color change. Likewise, studies in literature indicate no correlation between color change and variations in microhardness.[16.22] In this study, all samples underwent a daily 20-minute staining procedure for a duration of 15 days. Coffee producers report that consumers drink 2-3 cups of coffee daily, with each cup taking approximately 15 minutes to consume.[25] An in vitro application of 24 hours corresponds to an average of 1 month in the mouth. Within the limitations of this study, 300 minutes of in vitro coffee administration corresponds to an average of 6 days in the mouth. In order to ensure that the short-term application of staining and/or erosive agents was close to a procedure that could stimulate the oral environment, the samples were kept in a humidified environment with distilled water for 15 days, except for the 20-minute staining procedure. Abouelmagd et al [23], and Barve et al [15] also preferred distilled water as a storage medium in similar studies. In future studies, it would be appropriate to increase the duration of colorant and erosive beverage application. In the color measurements performed at the end of the staining procedure, it was found that 3D resin composites were less stained compared to direct and indirect composites. The assertion that the water absorption of 3D composites is elevated, leading to susceptibility to hydrolysis and structural degradation, as reported by Kim et al. in their study on the color stability of 3D resin composites, could be associated with the finding that the liquid absorption of these composites is both higher and more rapid.[19]

Due to this intense absorption, the liquid saturation of 3D composites increased and the diffusion of the colorant solution was limited, resulting in the material being less affected by the staining procedure. In this in vitro study, more color change was detected in coffee-treated samples compared to the other two application procedures. Roeder et al [24] reported that polar yellow pigments were the source of discoloration in coffee-treated samples in their study investigating the effect of various polishing systems on dental resin composites. It is known that there is a large amount of residual monomer on the surfaces of 3D resin composites.[18,19] As a result of the study, it was determined that the 3D resin composite material was more affected by coffee application after orange juice, unlike the indirect and direct composite groups. This effect is thought to be due to the lower resistance of the residual monomers on the surface of the 3D resin composite to the erosive effect. The color change after staining may be due to the silica-containing matrix and silane phase in addition to the phosphine oxide content in the universal direct resin composite group. Since the silane phase in the content allows liquid absorption, this type of composite may be more stained than 3D liquid resins. The reason why the indirect resin composite showed more discoloration after coffee application compared to the other groups may be due to the presence of camphoroquinone and TEGDMA (Triethylene glycol dimethacrylate), a hydrophilic monomer. On the other hand, the less coloration of the direct resin composite may be due to the predominance of hydrophobic monomers (BIS-EMA, zirconia, ceramic) in its structure.

Within the limits of the in vitro study;

- The microhardness values of all direct, indirect and 3D resin composites with different initial values were affected by the polishing process,
- The microhardness values of the resin composites were affected by the staining procedure and the maximum change in microhardness values was observed with the inclusion of orange juice in the procedure,
- In all resin composite groups, coffee caused the most color change and the material most affected by coffee was indirect resin composite,
- With the exception of the 3D resin composite, the coffee-on-orange juice procedure caused less discoloration than the coffee-only procedure,
- No correlation exists between the variation in microhardness and the color values of the materials.

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The Effect of the Phantom Models Used in Preclinic Education of 2nd Year Dental Students on the Success of Amalgam Restorations

Dişhekimliği 2. Sınıf Öğrencilerinin Klinik Öncesi Eğitiminde Kullanılan Fantom Modellerinin Amalgam Restorasyonların Başarısına Etkisi

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ABSTRACT

INTRODUCTION: The main factor in dental preclinical education, to learn working methods through realistic phantom jaws. The study aimed to compare the amalgam restorations prepared in preclinical education in different training models with objective evaluation criterion such as contour and contact.

MATERIAL and METHODS: Class II amalgam restorations made by second-year students in three groups: (S) stone model, (P) plastic model and (N) phantom model were evaluated by second-year faculty members and staff according to the determined criteria such as proximal cavity form, edge and contact compatibility, and compatibility of restorations' proximal and gingival areas (n=163). The restorations were prepared by the students in the phantom practice, considering, cavity preparation, liner, matrix-wedge, restoration phases and time allocated to each assignment (t=2 hours). McNemar-Bowker and Friedman tests were applied for the statistical analyses.

RESULTS: All models gave similar results in cavity preparation phase. However, there was no difference in the mesial or distal surfaces of amalgam restorations in stone and plastic models, the amalgam fit in the distal region in the phantom models was found more successful than others (p<0.05).

CONCLUSION: The use of phantom models that contains improved plastic teeth, which can imitate real teeth better will contribute more to student preclinical training in dental education.

Keywords: *Plaster model, Phantom model, Amalgam restoration, Preclinical training*

ÖZ

GİRİŞ: Diş hekimliğinde preklinik eğitimdeki en önemli unsurlarından biri fantom uygulamalarında çalışma yöntemlerini gerçeğe uygun fantom çeneler aracılığıyla öğrenmektedir. Bu çalışmada preklinik eğitiminde alçı, plastik ve gerçeğe uygun fantom modellerinde hazırlanan amalgam restorasyonların birbirleriyle kenar uyumu, kontakt gibi nitelikleri açısından karşılaştırılması amaçlandı.

YÖNTEM ve GEREÇLER: Çalışmada 2. sınıf öğrencilerinin alçı, plastik ve fantom modellerde yaptıkları Sınıf II amalgam restorasyonlar belirlenen kriterlere göre 2. sınıf öğretim üyeleri ve elemanları tarafından değerlendirildi (n=163). Restorasyonlar fantom pratiğinde öğrenciler tarafından her bir ödeve ayrılan birim süre (t=2 saat) göz önünde bulundurularak ve kavite, kaide, matris-kama, restorasyon aşamalarına uyularak hazırlandı. (A) alçı model, (P) plastik model ve (F) fantom model olmak üzere üç grup oluşturuldu. Her restorasyon Aproksimal Kavite Formu, Kenar ve Kontak Uyumu, Restorasyon Aproksimal ve Gingival Alanlarının Uyumu kriterleri üzerinden değerlendirildi. Verilerin istatistiksel analizinde öncelikle McNemar-Bowker ve Friedman testleri uygulandı.

BULGULAR: Kavite preparasyonunda tüm modeller benzer sonuçlar verirken, restorasyonların değerlendirmesinde, alçı ve plastik modellerde meziyal veya distal yüzeylerde fark bulunmadı. Fantom modellerde distal bölgedeki amalgam uyumunun meziyaldekine kıyasla daha başarılı olduğu tespit edildi (p<0.05).

SONUÇ: Gerçek dişleri daha iyi taklit edebilen ve özellikle fantom kafalara da adapte edilebilen geliştirilmiş plastik dişler içeren modellerin kullanımının, Restoratif Diş Tedavisi preklinik eğitimi sırasında, öğrenci manipülasyonuna daha fazla katkı sağlayabileceği kanısına varılmıştır.

Anahtar Kelimeler: *Alçı model, Fantom model, Amalgam restorasyon, Preklinik eğitim*

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INTRODUCTION

In restorative dentistry, preclinical education given to students is extremely important in terms of enhancing and strengthening the knowledge taught in theoretical courses with practical applications, gaining the necessary and sufficient manual skills for all kinds of clinical applications on the patient, and learning the ideal working positions. [1,2] Preclinical (phantom) studies, which are one of the most important elements of preclinical education, are also important in terms of teaching students direct and indirect working positions in the patient's mouth, holding hand tools correctly, working positions and using the light source correctly. [3] In addition, the mechanical and physical similarities of dental substitutes with dental tissues increase the mimicability of real clinical conditions in these practical applications, making it easier for students to recognize dental hard tissues.[4] Restorative treatments and procedures performed on materials with mechanical properties similar to enamel and dentin tissues play a role in making the education process more successful by increasing the learning levels and achievements of the students.[5,6]

Second- and third-year dentistry students first learn the restorative treatment procedures to be applied on the teeth of the patients in the clinic by applying the steps such as plaster models removed with special silicone molds, then plastic teeth placed in plastic jaws, and then cavity preparation, base and restorative material applications on extracted human teeth.[7,8] Plaster (stone) and plastic models are considered sufficient materials at the initial stage in teaching students the basic rules of practice due to their easy accessibility and applicability and the opportunity to work with a direct point of view.[7,8] However, the inability to provide indirect working conditions, the lack of a standard cavity design and restoration application due to the soft and heterogeneous nature of the materials are among the obvious disadvantages.[3] For these reasons, it is of great importance to use “Phantom heads and models” that have standard sizes and functions for each student that mimic the anatomy of the real head and neck region of the patients, and that the teeth on them are in real tooth hardness and forms.[2,9]

Working on models placed on phantom heads, which can mimic jaw movements and show occlusion relationships, has an important place in learning the terms used in the clinic and transferring them to practice.[9,10] For these reasons, educational activities using Phantom models improve students' practical outcomes compared to plaster models or plastic teeth placed in plastic molds. In addition, working with the appropriate position and angle in Phantom heads; In addition to contributing to the development of manual skills such as distance adjustment, hand-eye coordination, holding simple hand tools and mechanical tools such as anguldruva, it also provides students with many different practical information such as physiological and functional movements and limitations of tissues such as cheeks and lips.[5]

Another advantage of phantom heads over plaster and plastic models in imitating clinical conditions is their contribution to teaching students to work at maximum and minimum mouth openings, as they are cheek pads and joint movements compatible with real human head anatomy and physiology. The presence of cheeks in the heads and adjusting the vertical mouth opening especially in the posterior region plays a crucial role in the development of some fundamental haptic skills of students, in terms of preparing class 2 (OM/OD/MOD) cavities, applying different types of matrices to these cavities, insertion of restorative materials such as composites and amalgams, giving appropriate contours in the relevant teeth and ensuring contact relations.[11,12]

The aim of this study is to comparatively examine amalgam restorations made in plaster, plastic and phantom models in dental preclinical education in terms of their qualities such as cavity form, edge fit and contact.

MATERIALS and METHODS

Formation of Groups and Construction of Restorations

In the 2013 and 2014 academic years, second grade students (n=163) of Ege University Faculty of Dentistry were included in this study. All of the restorations which were evaluated in this study were performed by the 2nd grade students in Phantom Practice during the course of Restorative Dentistry. Three groups were formed: (S) plaster (stone) model, (P) plastic model (Klas Dental, Ankara, Turkey) and (N) phantom model (Nissin Dental Products Inc, Kyoto, Japan). Plaster models are made of type IV dental plaster (Die-Keen; Heraeus Kulzer Inc, South Bent, India.) Created. Prior to cavity preparation, the contacts on the plaster models were removed with metal amalgam sandpaper (Horico Dental, Hopf, Ringleb & Co. GmbH, Germany). While the typodont teeth were fixed with wax in plastic models, for phantom models special screws were used to fix the teeth.

In each group, under the supervision of the relevant faculty members and assistants, Class II (two and three-way) 4 mm deep amalgam cavities were prepared in accordance with the Black cavity rules. The occlusal width of the cavities was 1/3 of the intertubercle distance and the proximal margin was 1 mm above the enamel dentin border. MOD class II cavities were formed in the upper first premolar tooth and OM class II cavities were formed in the upper first molar tooth. No beveling was applied to the cavities because the final restoration will be amalgam. Zinc oxide eugenol (Alganol, Kemdent, Swindon Wiltshire, England), which is known to be the base material with the highest antibacterial effect and easy to apply was placed as a base material (liner) in the prepared cavities. [13] Ivory matrix was applied in OM/OD cavities and a ring (tofflemire) matrix was applied in MOD cavities. After the matrix application, the relevant teeth were wedged with wooden wedges of appropriate sizes (thickness and height) (Sycamore, Kerr Dental, Orange Co, CA, USA), considering the anatomical structure of the tooth, the form of the embrasure area, the location of the contact point and the distance between the teeth. Following the application of the base and matrix, amalgam restorations (Cavex non-gama 2 amalgam, RW Haarlem, Netherlands) were prepared by mixing the powder-liquid formulation with the amalgamator (Dentomat Compact Mixer, Dentsply, Konstanz, Germany) device in accordance with the manufacturer's instructions (Figure 1). Powder-liquid amalgam formulation was preferred because it was desired to manually adjust the hardening time of the amalgam according to the restoration size and to reduce the amount of residual amalgam to the maximum extent.

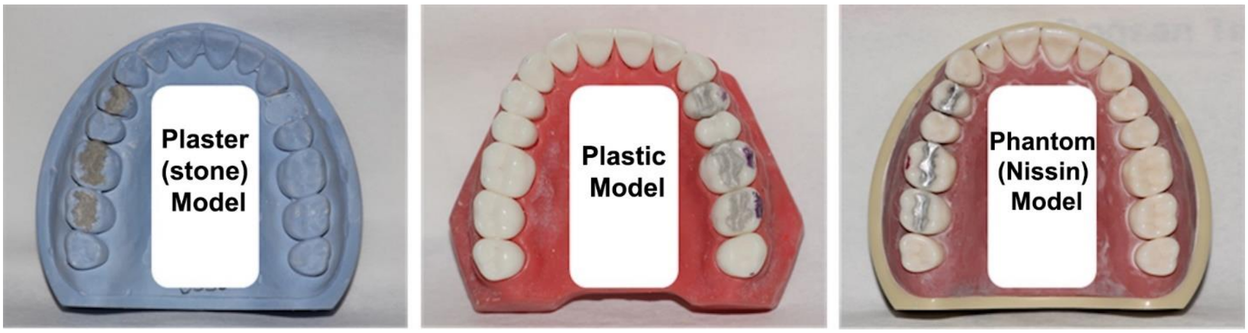

Figure 1.

Evaluation of Restorations

For the evaluation of the restorations, a scale was prepared in accordance with Black's principles, including cavity form, contact and edge compatibility criteria. Before the evaluation, faculty members and assistants were informed about the scale, and standardization was ensured among the observers. Evaluation for each tooth was carried out according to the specified evaluation criteria (Table 1). The edge fit criteria are shown in Figure 2.

Table 1: Criteria used in the evaluation of restorations

	Evaluation Criteria			
Aproximal Cavity Form (mesial, distal)	1: Normal		2: Not suitable	
Edge Fit (occlusal)	1: Normal	2: Redundancy (Flashing)	3: Indentation (Ditching)	4: Open margin
Contact (mesial, distal)	1: Normal	2: Open	3: Extreme	
Proximal area of the Restoration (mesial, distal)	1: Normal	2: Flashing	3: Open	
Gingival Edge of the Restoration (mesial, distal)	1: Normal	2: Flashing	3: Open	

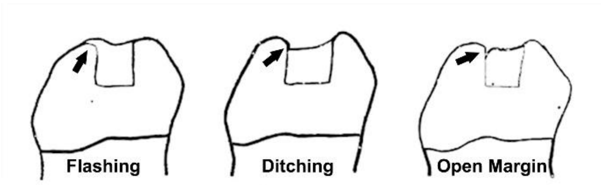

Figure 2.

In order to ensure the consistency of the observers within themselves, the evaluation stages were repeated at the end of 1 week and the average of the data obtained was recorded as the final grade. Criteria 2, 3 and 4 above, which were determined to provide calibration among observers, were standardized under the heading of unsuitable in line with the recommendation of the statistician. Thus, two main scores were determined under the heading of normal and inappropriate.

Statistical Analysis

The scores recorded by the observers were transferred to the computer environment. In the statistical analysis of the data, firstly, the McNemar-Bowker test was applied. In order to evaluate the level of achievement of the students on three different models, each parameter was recored as 'normal' and 'inappropriate' (other scores other than normal) and the Friedman test was applied. Thus, it was determined how many of the parameters the students performed normally in each type of model (for example, the number of students who did all of the parameters with normal scores or none of them). In pairwise comparisons, Wilcoxon test was applied. Statistical significance level was determined as p≤0.05.

RESULTS

In this study, which was created by evaluating the cavities and restorations prepared by 163 students on the plaster, plastic and phantom models used in preclinical dentistry education, it was seen that the type of model used did not statistically make a statistic difference in the mesial and distal contact harmony of the upper jaw first molar teeth and both mesial and distal contact fits of the premolar teeth (p≥0.05) (Table 2).

Table 2: Evaluation of restoration contacts

			EVALUATION CRITERIA			
Tooth no.	***Direction***	***Material***	***Normal***	***Not acceptable***		***p-Value***
				Open	***Excessive***	
Upper first molar tooth	M	S	107	30	26	0,266
		P	120	17	26	
		F	114	41	8	
Upper first premolar tooth	M	S	72	61	30	0,196
		P	74	41	48	
		F	87	64	12	
	D	S	79	55	29	0,227
		P	90	41	32	
		F	94	59	10	

* M; mesial, D; distal, S; Plaster (stone) model, P; Plastic model, N; Phantom (Nissin) model.

Table 2: Evaluation of apoximal cavity forms

			EVALUATION CRITERIA		
Tooth no.	***Direction***	***Material***	***Normal***	***Not acceptable***	***p-Value***
Upper first molar tooth	M	S	125	38	***a=0.000****
		P	76	87	***b=0.000****
		F	87	76	*c=0.294*
Upper first premolar tooth	M	S	104	59	***a=0.000****
		P	62	101	***b=0.000****
		F	74	89	*c=0.213*
	D	S	116	47	***a=0.000****
		P	55	108	***b=0.000****
		F	69	94	*c=0.120*

* M; mesial, D; distal, S; Plaster (stone) model, P; Plastic model, N; Phantom (Nissin) model.
** Statistically significant differences (p<0.05). **(S vs. P=a, S vs. N=b, P vs. N=c)**

Examples of contact images of amalgam restorations made in plaster, plastic and phantom models are shown in Figure 3. It was observed that the cavity forms prepared by the students in the mesial regions of the upper first molar teeth and the mesial and distal proximal regions of the upper first premolar teeth were better than those prepared in the plaster models (p≤0.05) (Table 3).

Figure 3.

Table 3: Evaluation of aproximal fit of restorations

			EVALUATION CRITERIA			
Tooth no.	***Direction***	***Material***	***Normal***	***Not acceptable***		***p-Value***
				Flashing	***Open***	
Upper first molar tooth	M	S	75	59	29	*0,247*
		P	73	72	18	
		F	86	43	34	
Upper first premolar tooth	M	S	90	52	21	***a=0.014**** *b=0.060* *c=0.649*
		P	67	74	22	
		F	72	58	33	
	D	S	78	50	35	***a=0.007**** *b=0.470* ***c=0.000****
		P	54	82	27	
		F	85	51	27	

* M; mesial, D; distal, S; Plaster (stone) model, P; Plastic model, N; Phantom (Nissin) model.
** Statistically significant differences (p<0.05).

The difference in model in the upper first molar teeth did not statistically change the amalgam fit in the proximal region. On visual examination, it was determined that amalgam condensation was made in the mesial proximal parts of the premolar teeth with no gaps and overflows at the tooth-filling interface in plaster models compared to plastics ($p \leq 0.05$). In the distal proximal parts of the premolar teeth, it was determined that the students showed more success in both plaster and phantom models than in plastics ($p \leq 0.05$) (Table 4).

Table 4: Evaluation of gingival amalgam concordance

			EVALUATION CRITERIA			
Tooth no.	***Direction***	***Material***	***Normal***	***Not acceptable***		***p-Value***
				Flashing	***Open***	
Upper first molar tooth	M	S	74	36	53	*0,206*
		P	88	33	42	
		F	86	44	33	
Upper first premolar tooth	M	S	88	18	57	*a=0.581* *b=0.105* ***c=0.019****
		P	94	20	49	
		F	73	53	37	
	D	S	83	19	61	*0,391*
		P	87	19	57	
		F	94	36	33	

* M; mesial, D; distal, S; Plaster (stone) model, P; Plastic model, N; Phantom (Nissin) model.
** Statistically significant differences (p<0.05).

Examples of proximal images of amalgam restorations prepared in plaster, plastic and phantom jaw models are shown in Figure 4. When amalgam condensations in gingival regions were evaluated, it was observed that only the upper first premolar teeth were statistically significantly more successful in the mesio-gingival regions in plastic models compared to phantom models ($p \leq 0.05$) (Table 5).

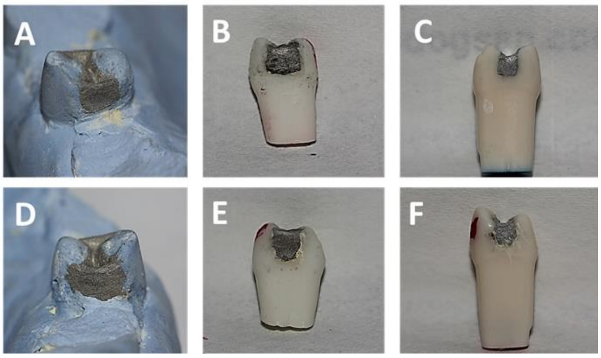

Figure 4.

Table 5: Comparison of mesial and distal contacts and proximal cavity forms in the upper first premolar tooth

Mesial and Distal Regions Contact Compatibility		**EVALUATION CRITERIA**			
Material	***Direction***	***Normal***	***Not acceptable***		***p-Value***
			Flashing	***Open***	
S	M	72	61	30	*0,472*
	D	79	55	29	
P	M	74	41	48	***0,017*****
	D	90	41	32	
N	M	87	64	12	*0,444*
	D	94	59	10	

Compatibility of Proximal Cavity Forms		**EVALUATION CRITERIA**		
Material	***Direction***	***Normal***	***Not acceptable***	***p-Value***
S	M	104	59	*0,096*
	D	116	47	
P	M	62	101	*0,265*
	D	55	108	
N	M	74	89	*0,500*
	D	69	94	

* M; mesial, D; distal, S; Plaster (stone) model, P; Plastic model, N; Phantom (Nissin) model.
** Statistically significant differences ($p<0.05$).

In the study, the effect of the direction of the prepared cavity on the results was examined. In this context, it was observed that statistically better contact fit was achieved in the distal proximal region in plastic models than in the mesio-lateral (Table 5), while the direction of the cavity did not statistically differ in all three models in terms of cavity form and amalgam fit in the proximal regions (Table 6).

In the evaluation of amalgam in the gingival region, the application in the mesial or distal region did not make a difference in plaster and plastic models, while the amalgam compatibility in the disto-gingival region was found to be statistically more successful in phantom models compared to the mesial ($p\leq0.05$) (Table 6).

When it is evaluated how many of the criteria included in the study are fulfilled appropriately by how many students; While there was no difference between the plaster-phantom model and the plastic-phantom model, the difference between the plaster-plastic model was found to be statistically significant ($p\leq0.05$) (Table 7).

Table 6: Comparison of amalgam-tooth concordance in the mesial and distal proximal region and gingival steps in the upper first premolar tooth

Proximal Region Amalgam – Cavity Compatibility		**EVALUATION CRITERIA**			
Material	***Direction***	***Normal***	***Not acceptable***		***p-Value***
			Flashing	***Open***	
S	M	90	52	21	*0,116*
	D	78	50	35	
P	M	67	74	22	*0,134*
	D	54	82	27	
N	M	72	58	33	*0,246*
	D	85	51	27	
Gingival Step Amalgam – Cavity Compatibility		**EVALUATION CRITERIA**			
Material	***Direction***	***Normal***	***Not acceptable***		***p-Value***
			Flashing	***Open***	
S	M	88	18	57	*0,899*
	D	83	19	61	
P	M	94	20	49	*0,395*
	D	87	19	57	
N	M	73	53	37	***0,026*****
	D	94	36	33	

* M; mesial, D; distal, S; Plaster (stone) model, P; Plastic model, N; Phantom (Nissin) model.
** Statistically significant differences ($p<0.05$).

Table 7: Evaluation of the final stage of the restorations

Material	Mean	Median	Standard deviation	*p-Value*
Plaster (S)	6,69	7	2,926	***a=0.001***
Plastic (P)	5,77	6	2,834	*b=0.151*
Nissin (N)	6,26	6	3,125	*c=0.059*

* a; Plaster, vs. Plastic, b; Plaster, vs. Nissin, c; Plastic, vs. Nissin
** Statistically significant differences (p<0.05).

DISCUSSION

Depending on the changing needs and increasing demands in dental education, the models and tools used in pre-clinical education have started to vary. [14] Accordingly, plaster models used in the past are now replaced by models that can better imitate natural tooth tissues. Phantom teeth, which are among the models and teeth that have started to be produced in parallel with these developments, and which we use in our work, are made of fiber-reinforced plastic homogeneously.[3] Although the material is softer than natural teeth, it creates a feeling of greater resistance during cavity opening than plaster and traditional plastic teeth. At the same time, these teeth can better imitate natural teeth in terms of contact and contour. [15] Suksudaj et al. reported in their studies that the compatibility of the materials used in preclinical education with real tissues is an important factor in developing the coordination and psychomotor skills required for dental students. [16]

In this study, 2nd grade students at the Faculty of Dentistry of Ege University. In the phantom laboratory, the class students were made to prepare cavities and subsequent restorations on the upper first molar and premolar teeth in plaster, plastic and phantom models. For statistical comparisons, the data were scored as 'normal' and 'inappropriate'. In the study design, criteria such as normal, flashing, ditching, and open margin were determined at the beginning.[17] The purpose of this approach is to express the characteristics identified by the 'non-acceptable' score in order to provide calibration among observers during the evaluation of assignments.[4] In the literature, there are very few studies examining the relationships between the materials used in the restorative preclinic, the restorations performed and the practical success of the students in dental education. [18,19,20] Therefore, the main reason for conducting this research is to examine the effect of the materials used by the students in the preclinical on the cavities they open and the success of the restorations they make.

In all cavity types prepared in this study, it was determined that the cavities opened in plaster models were partially better than those in plastic and phantom models. However, the fact that the contacts are removed with metal sandpaper before the procedures in plaster models is a misleading factor that makes it easier to see the interfaces and to shape these areas with hand tools during cavity preparation. For this reason, we think that plaster (stone) teeth and the cavities opened in these teeth are not an adequate and accurate simulation tool for dental education.

When the proximal amalgam concordances were compared, it was observed that plaster teeth were more acceptable for the mesial contacts of the first premolar teeth and for both plaster and phantom teeth in the distal contacts compared to plastic teeth. Since the teeth in the plastic jaw models are not screwed like the teeth in the phantom jaw models, we think that the upper first premolar tooth in the plastic models may have moved or stretched while the wedge was placed both mesial and distal. As a result, it was determined that amalgam restoration scores in the proximal region were worse in plastic teeth than in plaster and phantom teeth. In a study by Clancy et al., they argued that the difference between plastic and phantom jaw models directly affects the quality of the restorations. They reported that the feedback given by the supervisory faculty members and students after the application of the study also supported this result. [19]

In plastic models, gingival harmony in the upper first molar teeth were found to be better compared to phantom teeth. We believe that this may be due to the fact that the teeth are not fixed with screws in plastic jaw models, on the one hand, causing the amalgam to overflow, and on the other hand, providing an opportunity for cleaning the amalgam in the gingival. When the contacts of the restorations were evaluated in terms of cavity direction, it was seen that the distal contacts were formed better in the plastic models than in the mesials. Since plaster and plastic models could not be adapted to Phantom heads, and it was intended to standardize cavity preparation and restoration stages for all models, no work was carried out on the Phantom head. Therefore, it is thought that the fact that the students made the restoration by positioning the jaws in different directions so that they could work comfortably caused this result. As stated in the paragraph above, gingival amalgam compatibility in phantom teeth is better than mesial in distal proximal teeth; It is thought to be caused by working by positioning the jaws in such a way that the posterior teeth are close to the student. This result is consistent with similar studies in literature. [18]

When it is evaluated how many of the criteria included in the study are fulfilled "appropriately" by how many students; It was observed that the difference between plaster and plastic model was found to be statistically significant. As a reason for this, it has been concluded that plaster teeth are superior to plastic teeth because the manipulation of plaster teeth is more comfortable, the proximal regions are better seen as a result of removing the contacts with metal sandpaper, and accordingly more comfortable to work with.

CONCLUSION

As a result of the findings obtained from our study, although it is seen that students are more successful on plaster and plastic models, we believe that these materials will not be as effective as Phantom models in improving student manipulation because they are not close to the hard tissues of teeth. We think that the use of models containing fiber-reinforced plastic teeth, which can better imitate real teeth in terms of size and morphology before the transition from preclinic to clinic, and which can also be adapted to Phantom heads, can contribute more to the transition of students to clinical education.

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Dentists' Awareness, Knowledge and Experiences on the Use of 3D Print Technologies in Dentistry

Diş Hekimlerinin 3D Yazıcı Teknolojilerinin Diş Hekimliğinde Kullanımına Yönelik Farkındalıkları, Bilgileri ve Deneyimleri

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ABSTRACT

INTRODUCTION: This study evaluates the awareness and knowledge levels of dentists about 3D printing systems and the frequency of application of these systems in their clinical practice.

MATERIAL and METHODS: Data collection was carried out through a 19-question survey created through Google Forms. While the first 5 questions in this survey measure demographic characteristics such as gender, age, professional title, professional experience, and the institution, the other 14 questions consist of technical questions that measure the knowledge and experience of dentists about 3D printing technologies.

RESULTS: A survey of 358 dentists revealed 61.5% were general dentists, 22.9% were research assistants, and 15.6% were specialists. Knowledge of 3D printer technology was significantly higher among those in public hospitals and with ≤5 years of experience (P<0.05). While 75% did not use 3D printers, 12% used them several times a month, 8% several times a week, and 4% several times a day.

CONCLUSION: The level of knowledge about 3D printing technologies is higher in dentists who have five years or less of professional experience. It has been determined that the high-cost systems of 3D printing technology are the main factors limiting the use of the systems in dentistry practice.

Keywords: *3D Printing, Additive Manufacturing, Dentists, Surveys, Questionnaires*

ÖZ

GİRİŞ: Amaç: Bu çalışma, diş hekimlerinin 3D baskı sistemleri hakkındaki farkındalık ve bilgi düzeylerini ve bu sistemlerin klinik uygulamalarda kullanım sıklığını değerlendirmektedir.

YÖNTEM ve GEREÇLER: Veri toplama, Google Forms aracılığıyla oluşturulan 19 soruluk bir anket ile gerçekleştirilmiştir. Bu anketin ilk 5 sorusu, cinsiyet, yaş, mesleki unvan, mesleki deneyim ve çalışılan kurum gibi demografik özellikleri ölçerken, diğer 14 soru, diş hekimlerinin 3D baskı teknolojileri hakkındaki bilgi ve deneyimlerini ölçen teknik sorulardan oluşmaktadır.

BULGULAR: 358 diş hekimi arasında yapılan ankette, katılımcıların %61,5'i genel diş hekimi, %22,9'u araştırma görevlisi ve %15,6'sı uzman diş hekimi olarak belirlenmiştir. 3D yazıcı teknolojisi bilgisi, kamu hastanelerinde çalışanlar ve meslekte 5 yıl veya daha az deneyime sahip olanlar arasında anlamlı derecede yüksektir (P<0.05). Katılımcıların %75'i 3D yazıcı kullanmadığını, %12'si ayda birkaç kez, %8'i haftada birkaç kez ve %4'ü günde birkaç kez kullandığını bildirmiştir.

SONUÇ: 3D baskı teknolojileri hakkındaki bilgi düzeyi, meslekte beş yıl veya daha az deneyime sahip diş hekimlerinde daha yüksektir. 3D baskı teknolojisinin pahalı sistemlerinin, diş hekimliği uygulamalarında bu sistemlerin kullanımını sınırlayan ana faktörler olduğu belirlenmiştir.

Anahtar Kelimeler: *3D Baskı, Katmanlı Üretim, Diş Hekimleri, Anketler, Soru Formları*

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INTRODUCTION

Technological advancements have led to significant transformations in various fields, including dentistry, in recent years. The integration of digital technologies into dental applications has accelerated diagnostic and treatment processes while enhancing their precision. One of the most critical aspects of this technological evolution is 3D printing technology, which is increasingly being utilized in dentistry.[1]

3D printing is a technology that operates on the principle of additive manufacturing, enabling the production of patient-specific dental structures using computer-aided design (CAD) software. This method offers several advantages in dental applications, providing faster, more cost-effective, and patient-friendly solutions compared to traditional techniques. The use of 3D printing technology in dentistry is particularly concentrated in prosthodontics, orthodontics, oral surgery, dental implantology and endodontics.[2-9]

Today, 3D printers are used in prosthodontics to produce patient-specific restorations, making laboratory processes faster and more cost-effective. In orthodontics, 3D printing plays a crucial role, particularly in the production of clear aligners and customized bracket designs. Compared to traditional methods, patient data can be stored digitally and reproduced when needed, minimizing the necessity for physical storage.[4-7]

In oral surgery and dental implantology, 3D printing technologies enable the creation of patient-specific anatomical models, allowing for more precise preoperative planning and making surgical procedures more predictable.[8]

Despite these advantages, the extent to which 3D printing technology has been adopted in dental practice, the level of knowledge among dentists, and the potential barriers to its use remain unclear. Various studies have reported that dentists' awareness of 3D printing technologies varies significantly and that factors such as high costs and technical knowledge requirements may influence adoption rates.[10]

This study aims to assess dentists' knowledge and awareness of 3D printing technologies across a broad participant group, identify trends in its usage, and determine the barriers to its implementation. The findings are expected to contribute to the more effective integration of 3D printing technologies into dental education and clinical applications.

MATERIAL and METHODS

This study was conducted to measure the level of knowledge and awareness of dentists in Türkiye about 3D printing technologies. Data collection was carried out through a 19-question questionnaire created through Google Forms®. While the first 5 questions in this questionnaire measure demographic characteristics such as gender, age, professional title, professional experience, and institution of employment, the other 14 questions consist of technical questions that measure dentists' knowledge about 3D printing technologies.

A table summarizing the questionnaire items is provided in Table 1. The questions were developed based on a review of the literature and expert opinions from academics specializing in digital dentistry and 3D printing technologies. The questionnaire included questions regarding the level of knowledge, clinical application experience, and potential challenges in using 3D printing technologies in dental practice.

Table 1: Survey Questions on Dentists' Awareness and Knowledge of 3D Printing Technologies

Question Number	Survey Question
1	What is your gender?
2	What is your age?
3	What is your professional title? (General Practitioner, Research Assistant, Specialist)
4	How many years of professional experience do you have?
5	In which type of institution do you currently work? (State Hospital, Private Clinic, University Hospital)
6	Have you ever heard of 3D printing technologies in dentistry? (Yes/No)
7	Have you had the opportunity to use or observe 3D printing technologies? (Yes/No)
8	Do you have a 3D printer in your clinic? (Yes/No)
9	Do you use CAD/CAM systems in your clinic? (Yes/No)
10	What do you think is the best material for 3D printers? (Thermoplastic material, Light cure resin, Sintered powder, No idea)
11	In which applications do you use 3D printing technologies in your clinic? (Diagnostic Model Production, Prosthetic Restorations, Surgical Guide, Orthodontic Applications, No idea)
12	Do you think 3D printing technologies will be used more in the future? (Yes/No)
13	Would you like to attend a course/seminar to increase your knowledge about 3D printing technologies? (Yes/No)
14	What is the biggest barrier to using 3D printing technologies? (Expensive systems, Lack of sufficient practice, Complex technical information, Being unaware of 3D printers)
15	How often do you use 3D printers? (A few times a day, A few times a week, A few times a month, Never)
16	What factors do you think affect the efficiency of 3D printing in dentistry? (Cost efficiency, Ease of diagnosis and treatment, Prognosis, Technical aspects, Patient response)
17	Have you received any formal training on 3D printing technologies? (Yes/No)
18	Would you recommend the use of 3D printing technologies to your colleagues? (Yes/No)
19	What additional training or support would you need to use 3D printing technologies effectively?

The questionnaire application was carried out online and the participants were asked to confirm their voluntary participation in the research in the questionnaire forms. The survey was distributed via professional dental associations, university networks, and social media platforms to reach a diverse group of dentists across different regions of Türkiye. Inclusion criteria required participants to be licensed dentists actively practicing in Turkiye, while exclusion criteria included dental students and retired practitioners. The study was approved by Ordu University Clinical Research Ethics Committee (No: 2023/148). The sample set size was calculated in G*Power Software (version 3.1.9.2, Universität Düsseldorf, Germany) using effect size (0.50) with α=0.05 and 95% power. As a result of the power analysis, it was found that a total of at least 40 individuals were required for this study. Ultimately, 358 dentists participated in the survey, representing a diverse range of specializations and practice settings.

All data will be analyzed by entering them into the SPSS (SPSS for Windows 20.0; SPSS Inc, Chicago, Illinois) analysis program. After the normal distribution test was applied to the data, parametric tests were applied to the normally distributed data, while non-parametric tests were applied to the non-normally distributed data. The Pearson Chi-Square and Fisher Exact tests were used to analyze categorical variables, such as gender, professional title, institution, and professional experience, in relation to knowledge, experience, and the availability of 3D printing technologies in clinical practice. Additionally, descriptive statistics, including mean, standard deviation, and percentages, were used to summarize the demographic characteristics of the participants. The significance level was set at p<0.05 for all statistical evaluations.

RESULTS

A total of 358 dentists completed this survey. Survey questions regarding dentists' awareness and knowledge about 3D printing technologies are given in Table 1.

The demographic characteristics of the participants are presented in Table 2. The female participants (56.7%) were higher than the male participants (43.3%). While 61.5% of the participants were general dentists, 22.9% were research assistant dentists and 15.6% were specialist dentists. While 44.7% of the participants work in private clinics, 34.1% work in university hospitals and 21.2% work in public hospitals. The number of those with 5 years or less of professional experience was 57.8%, while the number of those with more than 5 years was 42.2%.

Table 3 displays the comparison of participants' responses regarding their knowledge of 3D printing technologies in dentistry. The rate of knowledge about the use of 3D printing technologies was found to be significantly higher for both those working in a public hospital and those with 5 years or less experience in the profession (p<0.05).

Table 2: Demographic characteristics of subjects participating in this study (n=358).

		N	%
% Gender	Female	203	56.7
	Male	155	43.3
Title	General Practitioner Dentist	220	61.5
	Research Assistant Dentist	82	22.9
	Specialist Dentist	56	15.6
Workplace	State Hospital	76	21.2
	Private Clinic	160	44.7
	University Hospital	122	34.1
Experience	5 or less than 5 years	207	57.8
	More than 5 years	151	42.2

Table 3: Comparison of dentists about use of 3D printing in dentistry and non-dentistry.

		Awareness about 3D Printing in Dentistry		**P**	**Awareness about 3D Printing in Non-Dentistry**		**P**
		Yes	No		Yes	No	
Gender	Female	184	19	0.616	161	42	0.208
	Male	138	17		131	24	
Title	General Practitioner Dentist	193	27	0.198	179	41	0.178
	Research Assistant Dentist	76	6		63	19	
	Specialist Dentist	53	3		50	6	
Workplace	State Hospital	63	13	0.035*	62	14	0.898
	Private Clinic	144	16		129	31	
	University Hospital	115	7		101	21	
Experience	5 or less than 5 years	192	15	0.038*	178	29	0.011*
	More than 5 years	130	21		114	37	

Significance levels, *P<0.05, **P<0.01, ***P<0.001

The comparison of the participants' answers to the questions 'Have you had the opportunity to experience 3D printer technologies?', 'Do you have a 3D printer in your clinic?' and 'Do you use CAD/CAM systems in your clinic?' are shown in Table 4. The rate of female participants experiencing 3D printer technologies was significantly higher than male participants (p<0.05). A statistically significant difference was found between the rates of experiencing 3D printer technologies according to the professional title of the participants (p<0.05). A significant difference was found between the experience rates of 3D printer technologies according to the institution where the participants worked (p<0.05). The participants' knowledge of whether there is a 3D printer in your clinic was found to be significantly different according to both the professional title and the institution where they work. A statistically significant difference was found according to the participants' gender, professional title, institution and professional experience (p<0.05). The comparison of the participants according to their answers to the questions 'Do you think 3D printer technologies will be used more in the future?' and 'Would you like to attend a course/seminar to increase your knowledge about 3D printer technologies?' is given in Table 4. There was no statistically significant difference (p>0.05) between the rate of the answers given by the participants according to their gender, professional title, institution and professional experience.

Table 4: Comparison of Dentists' 3D Printing Experience, Availability, and Future Perspectives

		3D Printing Experience		P	3D Printer Availability in Clinic		P	Milling Restorations Experience		P	Use of 3D Printing in Future Dentistry			P	Request to attend seminars about 3D Print		P
		Yes	No		Yes	No		Yes	No		Yes	No	No idea		Yes	No	
Gender	Female	62	141	0.003**	34	169	0.995	53	150	<0.001***	198	2	3	0.390	171	32	0.925
	Male	71	84		26	129		73	82		148	1	6		130	25	
Title	General Practitioner Dentist	72	148	0.029*	19	201	<0.001***	90	130	0.015*	210	1	9	0.067	187	33	0.144
	Research Assistant Dentist	32	50		29	53		20	62		80	2	0		72	10	
	Specialist Dentist	29	27		12	44		16	40		56	0	0		42	14	
Workplace	State Hospital	9	67	<0.001***	2	74	<0.001***	9	67	<0.001***	73	0	3	0.076	61	15	0.494
	Private Clinic	71	89		19	141		84	76		153	1	6		138	22	
	University Hospital	53	69		39	83		33	89		120	2	0		102	20	
Experience	5 or less than 5 years	73	134	0.387	40	167	0.128	63	144	0.027*	202	3	2	0.023*	173	34	0.761
	More than 5 years	60	91		20	131		63	88		144	0	7		128	23	

Significance levels, *P<0.05, **P<0.01, ***P<0.001

The comparison of the participants' answers to the question of which is the best material for 3D printers is given in Table 5. The participants' knowledge of the best material for 3D printers showed a significant difference between male and female participants (p<0.05).

The evaluation of the participants' answers to the question of in which applications do you use 3D printers in your clinic is given in Table 6. A statistically significant difference was found between the proportion of the answers given by the participants according to both the institution where they work and their professional experience (p<0.05).

Participants were asked the question 'What is the reason for inexperience in 3D printer technologies?'. The responses of the participants are given in Figure 1. 'expensive systems' (77%) was the most common answer, followed by 10% 'lack of sufficient practice', 10% 'complex technical information', and 3% 'being unaware of 3D printers'.

Participants were asked how often they use 3D printers and the responses are given in Figure 2. 75% of the participants reported that they do not use a 3D printer. 12% responded a few times a month, 8% a few times a week, 4% a few times a day.

Table 5: Comparison of dentists about 3D printing experience and 3D printer availability in clinics.

		Thermoplastic material	Light cure resin	Sintered Powder	No idea	P
Gender	Female	19	50	13	121	0.001**
	Male	35	35	17	68	
Title	General Practitioner Dentist	39	49	19	113	0.755
	Research Assistant Dentist	9	22	7	44	
	Specialist Dentist	6	14	4	32	
Workplace	State Hospital	11	13	8	44	0.387
	Private Clinic	29	36	13	82	
	University Hospital	14	36	9	63	
Experience	5 or less than 5 years	26	52	18	111	0.460
	More than 5 years	28	33	12	78	

Significance levels, *P<0.05, **P<0.01, ***P<0.001

Table 6: Comparison of dentists about 3D printing experience and 3D printer availability in clinics.

		Diagnostic Model Production	Prosthetic Restorations	Surgical Guide	Orthodontic Applications	No Idea	P
Gender	Female	19	131	11	25	17	0.800
	Male	16	97	9	15	18	
Title	General Practitioner Dentist	23	140	11	19	27	0.263
	Research Assistant Dentist	6	56	4	12	4	
	Specialist Dentist	6	32	5	9	4	
Workplace	State Hospital	7	46	4	4	15	0.012*
	Private Clinic	17	109	8	14	12	
	University Hospital	11	73	8	22	8	
Experience	5 or less than 5 years	20	143	8	23	13	0.027*
	More than 5 years	15	85	12	17	22	

Significance levels, *P<0.05, **P<0.01, ***P<0.001

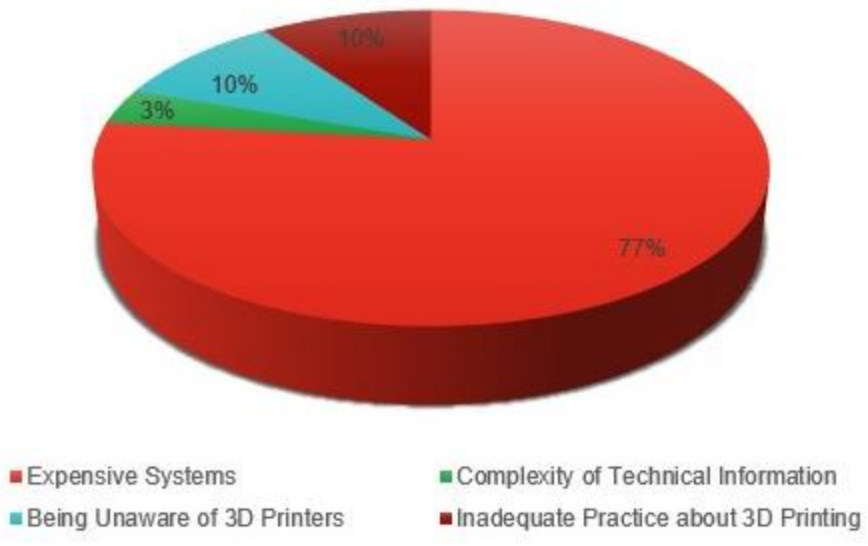

Figure 1: Showing the reason for inexperience

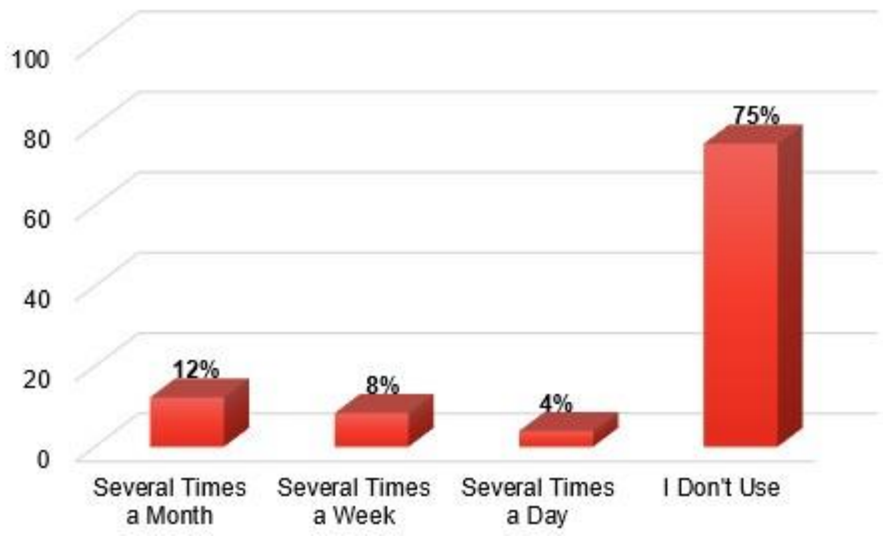

Figure 2: How often is it used

DISCUSSION

3D printer technology is defined as a manufacturing process that creates an object layer by layer, allowing the object to be formed by adding multiple layers to each other. 3D printer technology can also be defined as additive manufacturing or rapid prototyping. 3D printer technology is a promising technology in various fields such as medicine and dentistry, defense, art, architecture and engineering by enabling people to customize and produce their designs.[7]

The development of computer technology and software applications in recent years has contributed greatly to 3D printer technology. The 3D printing process starts with the design of a virtual image of the object to be produced, after which the information is converted into a digital file. The virtual design is realized thanks to a 3D modeling program. For this, CAD software is needed, which enables objects to be created from scratch. Examples of 3D printing technologies include SLA, inject printing, selective laser sintering (SLS), fused deposition modeling (FDM).[2]

Of the 358 dentists, 322 (89.9%) answered 'yes' to this question 'Do you have any information about the use of 3D printing technologies in dentistry? Of those who answered 'yes', 51.3% were female, 53.9% were general practitioner dentists, 32.1% worked at a university hospital and 53.6% had less than 5 years of professional experience. In a study conducted by Dhokar et al.[1] with 700 dentists in Maharashtra, 85.2% answered 'yes' to this question. Similar results have been observed about the use of 3D printing technologies in dentistry. In the study conducted by Chandran et al.[11] with 100 dental students, the rate of those who answered 'yes' was 58%. It is thought that the reason why this rate is lower is that it is a study for students. While the results of our study align with those of Dhokar et al.[1], a key difference is that our participant pool consists exclusively of dentists, whereas Chandran et al.[11] focused on dental students. This difference may account for the lower knowledge levels observed in their study, as students generally have limited clinical exposure. Furthermore, regional variations in access to technology and training opportunities may influence the level of awareness and utilization of 3D printing in different populations.

When we asked 'Have you had the opportunity to experience 3D printing technologies?', 133 out of 358 dentists (37.1%) answered 'yes'. In the study conducted by Chandran et al.[11] with 100 dental students, the rate of those who answered 'yes' was 12%(22). In the study conducted by Dhokar et al.[1]

In the study by Parikh et al.[12] 800 orthodontists in India were asked whether they used 3D Print manufacturing technologies. 47.5% of the respondents answered 'yes'. It was found that orthodontists had more opportunities to experience this technology, while the opposite was the case among students.[12] This variation in experience across different groups highlights the impact of professional specialization on exposure to emerging technologies. Orthodontists, who frequently rely on digital workflows, may have greater familiarity with 3D printing compared to general dentists or students. Therefore, future research should explore how training programs can bridge this gap for less-experienced practitioners.

52.7% of the participants answered, 'no idea' to the question 'What is the best material for 3D printer technologies?', while 23.7% answered 'light curing resin'. In the study conducted by Dhokar et al.[1] 58.7% of the participants gave the answer 'no idea' while 14% gave the answer 'light curing resin'. The results of the study are compatible with current study.[1]

In this study, 63.6% of the participants answered aesthetic and prosthetic restorations to the question 'Do you use 3D printer technology in your clinic in which applications?'. In the study conducted by Dhokar et al.[1] 43.4% of the participants answered in surgical guide preparation. While dentists in Türkiye primarily use this technology for aesthetic procedures, it is thought to be predominantly used for surgical applications in India.[1] The differences observed in application preferences may be attributed to regional differences in dental practice priorities, availability of materials, and regulatory frameworks. Further investigation is needed to determine whether economic and infrastructural factors influence these patterns of usage. This study highlights a significant awareness gap in the clinical application of 3D printing technologies among dentists. Addressing this issue requires integrating structured training modules on 3D printing into dental education curricula and postgraduate courses. Hands-on workshops, simulation-based training, and access to digital laboratories can enhance dentists' confidence and ability to utilize these technologies effectively in daily practice.

77% of the participants answered the question, "What is the reason for inexperience in 3D printer technologies?" with "high-cost systems." In contrast, in the study by Dhokar et al.[1], 30% of the participants stated that 3D printers were not available in clinics, while 29% attributed their inexperience to high costs. Considering that the reason for not being in clinics is high-cost systems, it can be said that the results of this study show similar results with the study of Dhokar et al.[1] Although cost remains a significant barrier, the availability of institutional funding or financial incentives may play a crucial role in increasing access to 3D printing technologies in clinical practice. Exploring cost-effective alternatives and promoting government or private sector investment could help overcome these limitations. This study has certain limitations that should be acknowledged. Firstly, the study was conducted exclusively in Türkiye, limiting the generalizability of findings to other geographic regions. The participant pool consisted only of licensed dentists, excluding dental students, technicians, and other stakeholders who may influence the adoption of 3D printing technologies. Additionally, the self-reported nature of the survey may introduce bias, as responses may not always reflect actual clinical behavior. Future studies with broader sample groups, including international comparisons and longitudinal data, are recommended to gain a more comprehensive understanding of the factors influencing the adoption of 3D printing in dentistry. The findings of this study shed light on the awareness, knowledge, and experiences of dentists regarding the use of 3D printing technologies in dentistry. Interestingly, our results indicate that dentists with less professional experience exhibited higher levels of knowledge and interest in 3D printing technologies. This trend could be attributed to various factors, including the integration of recent technological advancements into dental education curricula, as well as the innate adaptability of younger professionals to emerging technologies.[13,14]

Moreover, this study found that despite the majority of dentists being aware of the applications of 3D printing in dentistry, their level of practical experience with these technologies remains limited. This is consistent with previous research highlighting the gap between awareness and actual utilization of 3D printing technologies among dental professionals.[15,16] The discrepancy between knowledge and experience underscores the need for targeted interventions aimed at bridging this gap and facilitating the integration of 3D printing technologies into routine dental practice.

One notable barrier identified by participants in this study was the perceived costliness of 3D printing systems, with 77% of respondents citing this as the primary reason for their inexperience with technology. This finding aligns with previous studies highlighting cost as a significant hindrance to the adoption of 3D printing technologies in dentistry.[15,16] Addressing this barrier will require collaborative efforts from stakeholders, including universities, governments, and investors, to make 3D printing systems more affordable and accessible to dental practitioners.[17,18]

In light of these findings, several practical implications can be drawn. Firstly, there is a pressing need for targeted educational initiatives, such as courses, seminars, and training programs, aimed at enhancing dentists' knowledge and proficiency in 3D printing technologies.[19] By equipping dental professionals with the necessary skills and knowledge, these initiatives can facilitate the widespread adoption of 3D printing technologies and maximize their potential benefits in dental practice.[20]

Furthermore, efforts to make 3D printing systems more affordable and accessible should be prioritized to overcome financial barriers and promote wider adoption among dental practitioners.[21,22] This could involve exploring financing options, subsidies, or collaborative purchasing arrangements to mitigate the upfront costs associated with acquiring 3D printing equipment.[23,24]

In conclusion, while our study highlights the potential of 3D printing technologies to revolutionize dental practice, it also underscores the need for concerted efforts to overcome barriers to adoption and maximize the benefits of these technologies. By enhancing dentists' knowledge and accessibility to 3D printing systems, we can empower dental professionals to deliver more efficient, precise, and patient-centered care in the digital age. While this study provides valuable insights into the current awareness and application of 3D printing technologies in dentistry, further research is needed to explore long-term clinical outcomes and patient-related benefits. Future investigations should focus on evaluating the cost-effectiveness of 3D printing in dental procedures and its impact on treatment efficiency, precision, and patient satisfaction. Expanding research to include interdisciplinary collaborations with material scientists and biomedical engineers could also lead to innovative advancements in dental applications of 3D printing.

It was observed that although dentists have knowledge about the applications in which 3D printer technologies are used and think that they will be used more in the future, their opportunities to experience and clinical access are low. Making 3D printer technologies more affordable and providing the necessary support by universities, governments and investors will improve the application of 3D printers in dentistry.[24]

CONCLUSION

Our cross-sectional survey indicates that while most dentists accurately identify the principal clinical applications of 3D printing in dentistry. Notably, practitioners with under five years of experience reported significantly higher familiarity and interest, revealing an experience-related gap in hands-on training. Primary obstacles include equipment cost, lack of structured practical education, and uncertainty about workflow integration. We recommend a unified continuing-education initiative that combines concise theoretical briefings with dedicated hands-on workshops, equipping all dentists with the skills required for efficient and precise 3D-printed treatment planning and delivery.

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Comparison of Fracture Strength of Three Different Restorative Protocols for the Management of Re-Fracture of Teeth with Uncomplicated Crown Root Fractures

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ABSTRACT

INTRODUCTION: Fragment reattachment has been suggested as an interim emergent treatment modality for crown root fractures of permanent incisors. However, they may re-fracture leading to fragment dislodgement, even with in the acute phase. Hence, this in vitro study aimed to compare the efficacy of three management protocols of re-fracture of teeth with uncomplicated crown root fractures.

MATERIAL and METHODS: Sixty mandibular bovine incisor teeth were selected and were fractured to simulate uncomplicated crown root fracture. Fragments were rehydrated and reattached as per the etching–bonding protocol and stored in artificial saliva. They were refractured and randomly allocated to three groups for rebonding: Group-I(reattachment without rehydration), Group-II-(rehydration and reattachment), and Group-III-(restoration using composite). Universal testing machine was used to evaluate the force required to fracture them.

RESULTS: Group III showed the highest mean force (338.95±81.94N, 95%CI- 300.60, 377.30), followed by Group II (255.56±58.19N, 95%CI-198.32, 252.79). The lowest value of force required to fracture was observed in Group I (141.76±60.16N, 95% CI-113.60, 169.92).

CONCLUSION: The force required for fracture was greater in the teeth where composite restoration was done instead of re-bonding of dislodged crown-root fragment. Among the reattachment groups, the force required to fracture was greater when rehydration was performed.

Keywords: *Crown root fractures, fracture resistance, fragment reattachment, rehydration, traumatic dental injuries*

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INTRODUCTION

Traumatic dental injuries (TDI) are common in children and adolescents and they result in a significant health challenge due to its social, economic, and functional impacts.[1] Crown-root fracture is one of the severe forms of TDI involving both crown and root of a tooth.[2,3] It occurs because of oblique or horizontal impacts on the labial surface of the crown. Biomechanically, such forces result in stresses between the point of labial impact and the lingual or palatal aspect of cervical portion of the root.[3,4] The fracture occurs due to the tensile strain developing between the line joining the two stress zones.[2]

The International Association of Dental Traumatology (IADT) guidelines recommend fragment reattachment for immediate management of uncomplicated crown–root fractures in permanent teeth. It has to be performed during the acute phase and later a definitive treatment plan can be finalized. This may include orthodontic or surgical extrusion, root submergence, intentional replantation with or without 180-degree rotation, extraction or auto-transplantation. These guidelines also advise rehydration of the fragment as an important step prior to reattachment.[3,5] Reattached fragments can provide good and long-lasting aesthetics due to preservation of the gross anatomic form, color and surface texture of the tooth. It is more conservative and comparatively simple to perform. It also helps in restoring function and eliciting positive emotional response from the patients.[5,6,7] This may especially be important in crown root fractures in mixed dentition (8–12 years). In these cases, clinicians may be inclined to maintain vitality to achieve root maturity, and fragment reattachment or bonded restorations are useful. Additionally, strategies for prosthodontic rehabilitation are limited in this age group.[8]

The dental trauma literature related to fragment reattachment in crown root fractures is limited. Lokade et al. compared two rehydration protocols prior to simple reattachment. They found that significantly greater forces were required in teeth rehydrated by humidification.[8] Reinjury of injured teeth is common and it can result in dislodgement of the reattached crown root fragment.[9,10] Failures may also occur due to abnormal occlusal forces, premature contacts, and parafunctional habits.[7] If a dislodgement occurs, preparation is required on the two interfaces (the tooth and the fragment) covered with a layer of composite resin. This is followed by either re-bonding of the dislodged fragment or a composite restoration. To the best of our knowledge, none of the studies have assessed protocols related to re-bonding in the failed cases of reattached fragments in teeth with uncomplicated crown–root fractures. Hence, this study aimed to evaluate and compare the force required to fracture for three management protocols in such scenarios.

MATERIALS and METHODS

The protocol was approved by the Institute's Ethical Committee (IEC-942/24-11-2022) before the start of the study. Mandibular bovine incisors with similar dimensions (length, 26±2 mm; width, 15±2 mm, measured by a digital Vernier caliper, Mitutoyo Corporation, Tokyo) were collected. They were cleaned from debris and calculus using ultrasonic scaler and evaluated under 2.5X magnification (Hovivo Dental World, Delhi, India). Those free from cracks, caries, or any other kind of structural abnormalities were selected. Teeth were stored in normal saline at room temperature (25-28 degrees centigrade) until the start of the experiment. Due to the lack of previous data, a sample size of 20 teeth per group was estimated for this preliminary study.

The simulation of traumatic fracture was carried out as per the protocol described by previous study.[8] Briefly, an indelible pencil was used to mark a line extending from mesial line angle of the labial surface at the contact area to the junction of the cervical and middle thirds of the distal line angle of the labial surface of the root. The line was mirrored to the lingual surface of the tooth. A diamond disc mounted on a slow speed hand piece was used along this line to create a groove of 1 mm depth (Figure 1A). Force was manually applied perpendicular to the fracture line, using a dental mallet. This could result in simulation of a crown root fracture (Figure 1B and 1C). All the steps were performed by one trained and calibrated operator with prior experience in this area. This was done to reduce inconsistencies in the amount and direction of force applied. Tooth stumps were stored in artificial saliva, while, the fragments were subjected to drying at room temperature (25-28 degrees centigrade) and pressure (1001–1004 hPa) for 24 hours.

The next step involved rehydrating the fragments for 15 minutes in a self-designed humidification chamber which had been developed in 2019 and used in previous studies. It comprises of two air tight boxes of plastic placed one over the other and interconnected by a hole of 2 cm diameter. A humidifier procured from market is placed in the lower compartment and the lid of the upper compartment is closed to obtain 82±2% humidity when operated for 10 minutes. The humidity measurements are done by an industrial grade hygrometer whose probe is housed in the upper box. The fragment samples that are to be humidified are kept in a perforated tray in the upper box so that rehydration by humidification can be achieved.[8,11,15] The fragments and tooth stumps were dried by using a cotton roll, and acid etching was performed for 30 seconds (Scotch Bond Multipurpose etchant, 32% phosphoric acid, 3 M/ESPE, São Paulo, Brazil). It was washed with distilled water for 10 seconds and a three-way syringe was used to dry the samples for 10 seconds. A bonding agent (Adper Single Bond 2, 3 M/ESPE, São Paulo, Brazil) was applied using a microbrush and light-cured for 10 seconds (Elipar, 3 M ESPE, USA). A flowable nanocomposite (A2 shade, Filtek™ Z350XT, 3 M/ESPE, São Paulo, Brazil) was applied to the tooth stump and the fragment, and their positions were verified prior to curing. The excess composite was removed, and curing was performed for 10 seconds on each side (Figure 1D). All samples were again stored in artificial saliva and thermocycled by using two baths having a temperature differential of 6–60°C for 2000 cycles and a dwell time of 30 seconds in each bath. This was done to simulate the variations in the temperatures present in oral cavity to which restorative materials and reattached fragments are subjected to.[7,8,11]

In the subsequent part of the experiment, a computer-generated sequence was used to randomly allocate the samples to (n=20 each): Group I-reattachment without rehydration; Group II-rehydration with humidification and reattachment; and Group III-composite restoration. A mallet was used to apply force perpendicular to the labial surface at the visible fracture line for each sample (Figure 1E). This was also performed by the same operator as previously described. It resulted in refracture and dislodgement of the reattached fragments. The fragments and tooth stumps were coded by using Arabic numbers 1 to 60 so that they could be matched during other steps. They were stored in artificial saliva for 24-48 hours period, till the next stage of experimentation.

An ultrasonic scaler tip was used to mechanically abrade and remove the visible resin from all the fragments and tooth stumps. Simple reattachment was performed by using the etching and bonding protocol without rehydration in Group I, whereas the fragments were rehydrated by placing them in a humidification chamber for 15 minutes prior to reattachment in Group II. The fragments in Group III were discarded and nanohybrid composite (A2 shade, packable Filtek™ Z350XT, 3 M/ESPE, São Paulo, Brazil) was used in increments of two millimeters to restore the tooth to normal size, shape and contours as per the recommended protocol of etching and bonding. The composite was cured for 30 seconds for each increment.

Thermocycling was performed again using the protocol described above. The samples were embedded in an acrylic cylinder (21 mm in length) so that the fracture line remained exposed for testing the force required to fracture (Figure 1F). A tangential load of 500 kg at a speed of 1 mm/min in the incisal direction was applied via a universal testing machine (MTMS, India). It was applied on the labial surface of the samples at the junction of the incisal and middle thirds on the fracture line via a blunt needle force applicator. The force required to refracture was evaluated for each sample (Figure 1G). All the experiments were performed within four weeks of sample collection, and attempts were made to follow the best practices of storing the bovine teeth. The data were entered into a Microsoft Excel Sheet, and the statistician was blinded to the nature of the groups. Statistical analysis was performed with Stata-14 (USA) via ANOVA and Tukey's post hoc test.

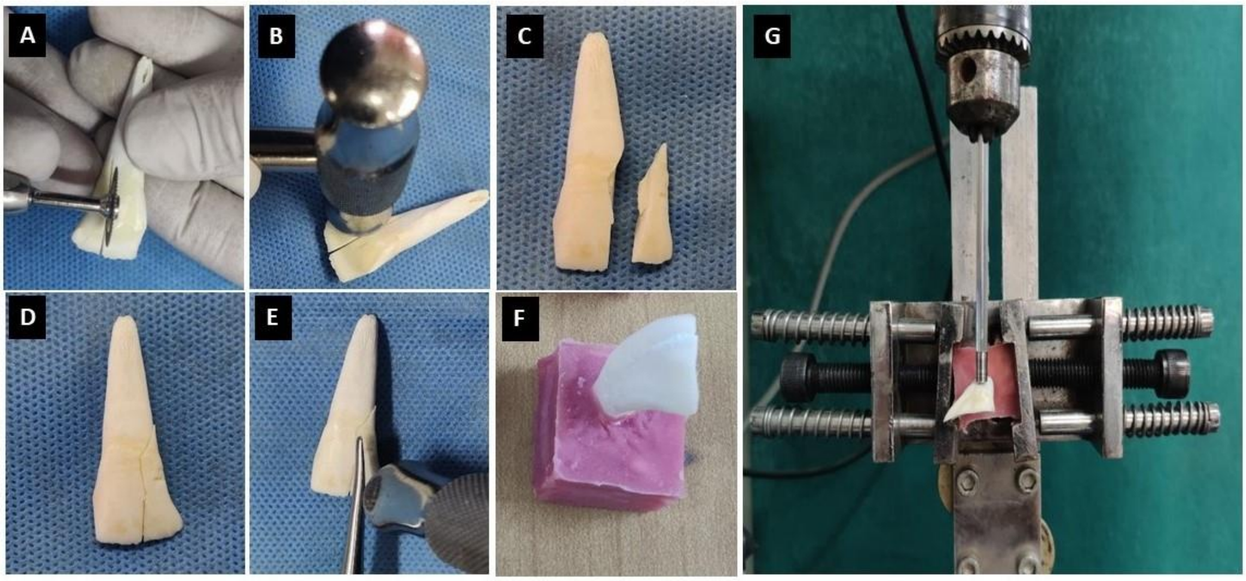

Figure 1: Showing the steps of preparation of the bovine tooth samples and their testing- A) Groove preparation B) and C) Fracture D) Re-approximation of the fragment and tooth E) Re-Fracture F) Reattached sample after thermocycling and being mount in the acrylic for final testing G) Testing of sample by a universal testing machine.

RESULTS

The highest mean force for refracture was seen in Group III (338.95 ± 81.94 N, 95% CI-300.60, 377.30), followed by Group II (255.56 ± 58.19 N, 95% CI-198.32, 252.79). The lowest amount of force required to refracture was recorded in Group I (141.76 ± 60.16 N) (95% CI-113.60, 169.92) (Table 1, Figure 2). The mean differences between all the groups were statistically significant (<0.001) (Table 2).

Table 1: Mean force required to fracture (Newton) and the results of statistical analysis via one-way ANOVA.

Groups	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval		ANOVA
					Lower Bound	Upper Bound	
Group I	20	141.7635	60.16937	13.45428	113.6034	169.9236	Between Groups -Sum of Squares 391760.184, DF−2 Mean Square 195880.092
Group II	20	225.5620	58.19187	13.01210	198.3274	252.7966	within Groups- Sum of Squares, 260725.076 DF−57 Mean Square 4574.124
Group III	20	338.9540	81.94953	18.32447	300.6004	377.3076	F Value- 42.824 p < .001

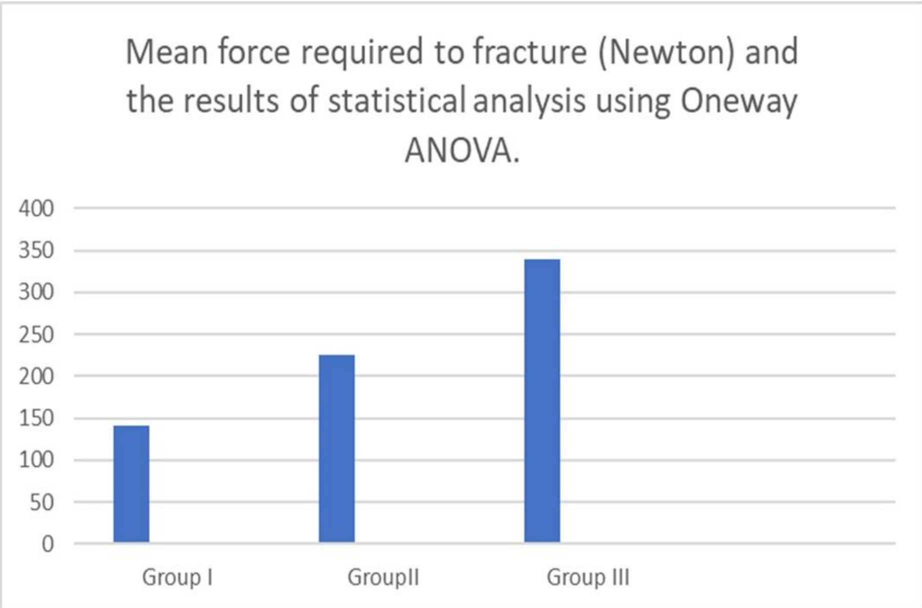

Figure 2: Mean force required to fracture the re-reattached fragments in the three groups- Group I- Reattachment without rehydration, Group II- Reattachment with rehydration, Group III- Composite restoration.

Table 2: Mean differences between the groups and their statistical significance (Tukey's post hoc tests)

Group Comparisons	Mean Difference	Standard Error	Significance	95% Confidence Interval	
				Lower Bound	Upper Bound
Group I vs Group II	-83.79850	21.38720	≤ 0.001	-135.2651	-32.3319
Group I vs Group III	-197.19050	21.38720	≤ 0.001	-248.6571	-145.7239
Group II vs Group III	-113.39200	21.38720	≤ 0.001	-164.8586	-61.9254

DISCUSSION

Reattachment of the fractured fragments and their stabilization are recommended as immediate management in uncomplicated crown–root fractures until definitive treatment can be performed. Although it is difficult to obtain adequate access and isolation when intra-alveolar fracture lines extend very deep, effective fragment reattachment protocol has been suggested.[3] This can save the patient from pain due to mobile fragments and the distress of undertaking extensive treatment procedures during the acute phase of the injury. It also helps in providing psychological consolation. The greatest concern, however, is the predictability of treatment and sequelae of dislodgement of reattached fragments within few hours or days.[7,13]

Khandelwal et al evaluated the effectiveness of fragment reattachment in crown root fractures and reported reasonable short-term success, even in teeth with pulp exposures. However, it was based on a lower level of evidence from multiple case reports and case series.[4] The reasons for dislodgement may be procedural problems, repeat trauma episodes, or abnormal occlusal forces.[7,8] The dislodgement of such fragment can lead to further complications such as pulp exposure and necrosis and require the extensive treatment procedures that can be avoided in the acute phase of trauma.[8] Since the treatment options after dislodgement of reattached fragments in teeth with crown root fractures had never been explored, this in vitro experiment using bovine incisors was designed. It was envisaged that even though the results would not have a high level of evidence, they would discern a trend that may be reassessed in clinical trials in the future.

The best practices for in vitro experimentation were followed to reduce confounding factors and simulate oral conditions.[1,14,15] The choice of bovine teeth and their standardization were based on previous studies and similarity of bovine and human dentin.[5-7] The simulation of fracture lines and other steps of the experiment were also performed as per the established protocols.[7,8,11,15] The lowest force required to fracture the reattached fragments was observed in teeth where reattachment was performed without rehydration, whereas the highest force required was observed in the teeth that were restored using nanohybrid composite. The micromechanical bonding to the enamel, dentin, and cementum surfaces results in a layer of residual composite resin after the reattached fragments are dislodged. As a result, the dentinal tubules no longer remain conducive to the penetration of bonding agents and subsequent bonding with the composite.[15] Even with the greatest efforts to remove the visible layer of the resin, complete removal might not have been possible in the present experiment. Among the teeth managed by fragment reattachment, the greater force required for fracturing the fragments in Group II can be attributed to the humidification of the abraded dentin, which allows better penetration of bonding agents, even in these cases.[13] This finding was similar to the observations of previous studies.[8,11,14,15] The rehydration has been a known factor for improving the prognosis of the fractured teeth and the humidification chamber helps in making it more objective and scientific.[8,11,15] The incremental layering of the composites and curing of each layer might also have resulted in better polymerization and increased resistance to fracture. As a result, the more consistent treatment option in such cases seems to be a light-cured composite restoration after adequate removal of the resin tags from the broken tooth stumps, preferably under magnification. The superiority of this approach over re-bonding fragments was also observed in uncomplicated crown fractures.[15] Further, previous works have emphasized the role of shear bond strength when it comes to the fragment reattachment or composite resin-based restoration of fractured teeth. Though the differences between the conventional and fiber reinforced composites were not significant, they were much lower than the intact tooth. It is of great importance that most of the impacts leading to re-injury cause shearing stress and tangential loads that lead to re-fractures.[16] Although more complex in crown root fractures, it may be a viable solution when isolation can be established. This research has clinical application in immature permanent teeth or in age groups where options for prosthodontic rehabilitation are limited. Since, there are areas of concerns and weaknesses associated with composite resin restorations in crown-root fractures, the comprehensive rehabilitation by using full coverage crowns and post endodontic reinforcement must always be considered in intermediate and long term follow ups. This can be a potential area for future research with improvement in bonding materials. Further, the trends observed need clinical validation using *in vivo* study designs.[7]

Analysis of the tooth stump and fragment surfaces by using profilometry or scanning electron microscopy could have been important for characterizing the samples in greater detail. However, it was not performed because of the preliminary nature of the experiment and must be viewed as a limitation. Recently, the recommendation regarding simple reattachment as the best method for fragment reattachment has been challenged with emerging evidence in favor of different reinforcement protocols.[17] This was also not explored in the present study and can be an area of exploration for future researchers.

CONCLUSION

Within the limitations of the present study, it may be concluded that the force required to fracture was highest in the teeth where composite restoration was performed instead of re-bonding of dislodged crown-root fragment. Among the reattachment groups, the force required to fracture was higher when rehydration using humidification was performed.

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Evaluation of The Effect of Consecutive Dental Visits on Dental Anxiety of Pediatric Patients

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ABSTRACT

INTRODUCTION: Childhood is period when dental anxiety is most common, and this behavioural disorder, which is common during this period, is associated with fear of dental procedures and the environment of the dental clinic. The study aimed to evaluate effect of two separate dental sessions on anxiety level of children in dental clinic.

MATERIAL and METHODS: 240 children aged 6-9 years who have two caries on mandibular primary molars were included current study. Before and after the dental procedures The Abeer Children Dental Anxiety Scale (ACDAS) was applied to all participants in consecutive visits. Physiological parameters were measured with pulse oximeter every five minutes during dental treatments. SPSS software (version 22.0, SPSS Inc, Chicago) was used for statistical analysis.

RESULTS: Participants' mean age was 6.9±1,18 years. Both preoperative and postoperative ACDAS scores were significantly higher at the first visit than at the second visit. Statistically significant differences were observed in heart rate scores between treatment sessions (p<0.001).

CONCLUSION: The results of this study demonstrated that consecutive dental visits decreasing the dental anxiety level of children aged 6-9 years. These findings emphasize the significance of consecutive treatment visits in pediatric dentistry.

Keywords: *Pediatric patients, dental anxiety, consecutive dental visits, behaviour management*

ÖZ

GİRİŞ: Çocukluk dönemi dental anksiyetenin en yaygın görüldüğü dönemdir ve bu dönemde sık görülen bu davranış bozukluğu, dental prosedürlerden ve diş kliniğinin ortamından korkmakla ilişkilendirilmektedir. Bu çalışmanın amacı, ardışık diş hekimi ziyaretlerinin çocukların diş kliniğindeki anksiyete düzeyi üzerindeki etkisini değerlendirmektir.

YÖNTEM ve GEREÇLER: Çalışmaya, mandibular süt birinci molar dişlerinde iki çürüğü bulunan 6-9 yaş arası 240 çocuk dahil edilmiştir. Diş tedavileri öncesinde ve sonrasında Abeer Çocuk Diş Anksiyete Ölçeği (ACDAS) tüm katılımcılara ardışık ziyaretlerde uygulanmıştır. Fizyolojik parametreler, diş tedavileri sırasında her beş dakikada bir puls oksimetre ile ölçülmüştür. İstatistiksel analizler için SPSS (versiyon 22.0, SPSS Inc, Chicago) yazılımı kullanılarak analiz edilmiştir.

BULGULAR: Katılımcıların ortalama yaşı 6,9 ± 1,18 yıldır. Hem preoperatif hem de postoperatif ACDAS skorları ilk ziyaret sırasında ikinci ziyarete göre anlamlı derecede yüksekti. Tedavi oturumları arasında kalp atım hızı değerlerinde istatistiksel olarak anlamlı farklar gözlemlenmiştir (p < 0,001).

SONUÇ: Bu çalışmanın sonuçları, ardışık diş hekimi ziyaretlerinin 6-9 yaş arası çocukların dental anksiyetesini azalttığını göstermektedir. Bu bulgular, pedodontide ardışık tedavi ziyaretlerinin önemini vurgulamaktadır

Anahtar Kelimeler: *Pediatrik hastalar, dental anksiyete, ardışık diş hekimi ziyaretleri, davranış yönlendirmesi*

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INTRODUCTION

Anxiety is related to fear, but these terms are used to describe two different conditions. Therefore, the terms anxiety and fear are debated by researchers. Dental anxiety is a state of apprehension that harmful practices will occur during dental treatments. In contrast, fear occurs as a normal emotional response to threatening situations.[1] In a systematic review, dental anxiety was reported to be a behavioural disorder occurring in 10-20% of children worldwide.[2] Childhood and adolescence are both the most common periods of dental anxiety, with prevalence rates ranging from 20% to 50%. This behavioural disorder, which is common during these periods, is associated with fear of dental procedures and the environment of the dental clinic.[1-3] In this context, researchers have reported that children with high dental anxiety have more decayed, missing and filled teeth.[4] Behaviour management problems in dental practice also occur as a result of dental anxiety, phobia or fear.[5] Due to these disadvantages, dental anxiety is recognised as a factor with negative effects on oral health. For dentists, it is difficult to distinguish between phobia and fear and therefore these conditions are referred to as dental anxiety.[6] When planning dental treatment of children, dental anxiety and fear are the most important components for understanding patients' cooperation and behaviour towards dental procedures. According to their attitudes towards treatment in the dental clinic, children are categorised as cooperative, potentially cooperative and non-cooperative.[5] Existing non-pharmacological techniques for behaviour management can be used for cooperative and potentially cooperative children, except for children who lack the ability to cooperate. This is because lack of ability to co-operate refers to children who are too young to communicate and who have partial or total disabilities.[7, 8] Most of the research on dental anxiety is based on questionnaires, which are considered the most acceptable method for assessing anxiety in children who have the cognitive ability to express their feelings on a questionnaire.[9-11] The use of the Abeer Children Dental Anxiety Scale (ACDAS) is an acceptable practice for determining dental anxiety in children aged 6 years and older.[7] Because ACDAS evaluating to anxiety of children by asking questions dentist, parents and children. This situation supports to in all its aspects evaluating anxiety of children. Therefore, further studies on Turkish paediatric patients using the ACDAS, which includes cognitive questions and has proven Turkish validity, are necessary to better understand the causes of dental anxiety and to assist paediatric dentists in behavioural management.[12]

Researchers have proposed that a child’s initial reaction to a dental visit is largely influenced by fear of the unknown.[13,14] Furthermore, anxiety levels tend to be elevated in children who present to the dental clinic with pain. Venham et al. reported that negative behavioral responses were particularly pronounced during initial visits.[15] The first dental visit plays a pivotal role in sensitizing the child to subsequent dental procedures. Nevertheless, successive dental appointments may facilitate a process of systematic desensitization, thereby reducing anxiety levels over time. This phenomenon aligns with the perspective adopted in numerous studies, which conceptualize dental anxiety as an adaptive process—one that often originates in childhood and can be progressively mitigated through appropriate behavioural interventions.[13-15]

Studies suggest that dental anxiety in children may be related to adjustment to the dental clinic environment.[16,17] Therefore, dental procedures in the clinical setting may affect children's dental anxiety level. However, children's adaptation to the dental clinic environment may reduce the severity of dental anxiety. Sequential dental visits may positively affect the cooperation of paediatric patients and increase their adaptation to the dental clinic environment and reduce their anxiety levels.

The aim of this study was to evaluate the effect of consecutive dental visits on anxiety levels in group of Turkish children aged 6-9 years using physiological parameters such as heart rate and oxygen saturation and an anxiety scale.

MATERIALS AND METHODS

The Ethics Committee of Mehmet Akif Ersoy University approved the current study (No: GO 2024/401), which was conducted in accordance with the Declaration of Helsinki. All participants provided informed consent. The trial was registered at ClinicalTrials.gov (NCT06266156) on 12/02/2024.

The study aimed to determine an effect size of 0.88 with a significance level and power of 0.05 and 95%, respectively. The required sample size was calculated as 200; however, to account for possible data loss, the sample size was selected as 260. Participants were selected from healthy children aged 6-9 years with no mental or physical disability and no previous dental experience, who did not need emergency dental intervention, and who had dental caries limited to enamel and dentin and were included in ASA1 according to the American Society of Anaesthesiologists guidelines.[18] Children with physical or mental disabilities, without parental consent or with cardiovascular diseases affecting physiological parameters such as blood pressure, pulse rate or oxygen saturation were excluded. Of the 260 invited children, 20 were excluded because they did not attend the second visit, and the procedures were performed on 240 participants who met the inclusion criteria. Consecutive appointments were organised with a maximum interval of 2 weeks. The flowchart of study process is shown in Figure 1.

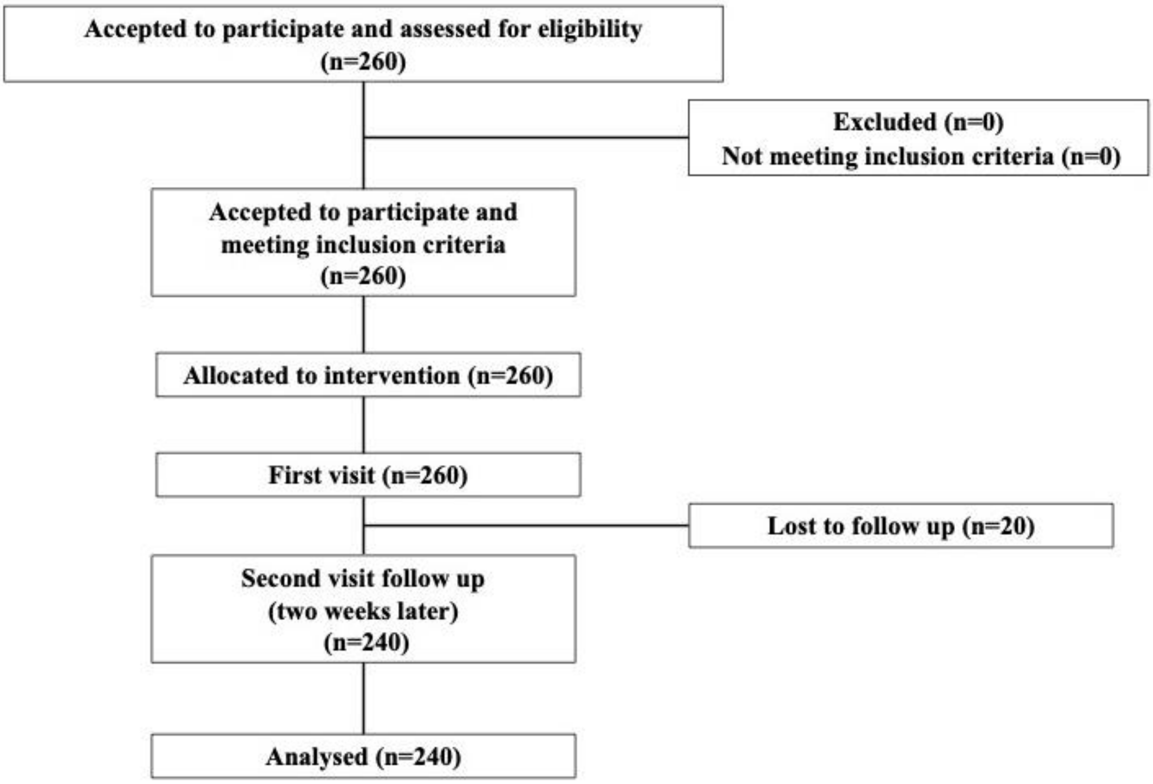

Figure 1. The flowchart of entire process from participant selection and end of study

In order to measure anxiety, a three-part ACDAS was used, in which the child was evaluated, and dental and cognitive parameters were measured in addition. In the dental part of the scale, which consists of 19 questions in total, there are 13 questions in which children express their feelings using facial expressions and are scored from 1 to 3. Total scores ranged from 13 to 39, with scores of 26 and above indicating anxiety (Figure 2). The child's parents and the paediatric dentist (HT) completed the cognitive and child assessment sections of the scale. The children were initially examined clinically and radiographically without any dental treatment. At subsequent visits, all participants received topical (lidocaine 5% gel) and buccal infiltration anaesthesia (68 mg articaine hydrochloride + 0.017 mg epinephrine / 1.7 ml) prior to cavity preparation in the mandibular primary first molar. All carious lesions were limited to dentinal caries based on conventional radiographic and clinical assessment, ensuring moderate lesion depth in mandibular primary first molars, consistent with Class I or II cavity preparations. The ICDAS classification was used, the selection of lesions was standardized to ensure moderate, non-complex lesions (ICDAS Class 5). Rubber dam isolation, use of the same compomer restorative material, and a uniform restorative technique were applied in all cases. All treatments were performed by the same pediatric dentist (HT) using the tell-demonstrate-apply behavioural guidance technique. The ACDAS was administered before and after the procedure during both visits.

Objective anxiety symptoms were assessed by measuring heart rate and oxygen saturation using a pulse oximeter (High Accuracy Fingertip Pulse Oximeter Model: XM-112, Joytech Sejoy, CHINA). These physiological parameters were recorded every 5 minutes during dental procedures in both visits.

Statistical Analysis

SPSS software (version 22.0, SPSS Inc, Chicago) was used for statistical analysis. Sample size calculations were performed using G-Power (version 3.1.9.6, Germany). Normality of the data was determined by Kolmogorov-Smirnov and parametric tests. According to normality tests, all data obtained were normally distributed. In descriptive statistics, numerical and categorical variables are presented as mean, standard deviation and percentage, respectively. The differences between the heart rate, oxygen saturation and ACDAS scores of the participants were determined using two sample t-test.

A. Dental Part

I would like you please to tell me how relaxed or scared you feel at the dentist. Please use the scale below from 1 to 3 and tick (✓) under the face that shows us how you feel now.

How do you feel about:	1: Happy 1	2: Ok 2	3: Scared 3
1. Sitting in the waiting room?			
2. A dentist wearing a mask on his face?			
3. Laying flat on the dental chair?			
4. A dentist checking your teeth with a mirror?			
5. Having a strange taste in your mouth e.g. a filling or gloves?			
6. Having a "pinch" feeling in your gum?			
7. The feeling of numbness (fat lip or tongue)?			
8. A dentist cleaning your teeth by buzzy electric arm that's spraying water?			
9. The sounds that you hear at the dentist?			
10. The smell at the dentist?			
11. Having a tooth taken out?			
12. Wearing a small rubbery mask on your nose to breathe special gas to help you feel comfortable during treatment?			
13. Having a "pinch" feeling on the back of your hand?			

B. Cognitive Part

14. Do you feel shy at the dentist? 1. Yes 2. No
15. Do you feel shy because of the way your teeth look? 1. Yes 2. No
16. Are you worried about losing control at the dentist? 1. Yes 2. No

C. Child Assessment

For legal guardian:

17. Has your child had previous dental treatment? 1. Yes 2. No
18. How do you expect your child's behaviour today?
    1. Happy 2. Ok 3. Scared

For operator:

19. At the end of this visit, what is your rating for the child's behaviour?
    1. Happy 2. Ok 3. Scared

Figure 2. Information about Abeer Children Dental Anxiety Scale (ACDAS)

RESULTS

Descriptive analyses of the participants are shown in Table 1. The minimum and maximum ages of the children were 6 and 9 years, respectively, and the mean age was 6.9±1.18 years. Participants were distributed across age groups as follows: 6 years (n=65), 7 years (n=64), 8 years (n=55), and 9 years (n=56). Comparative analysis of ACDAS scores and physiological parameters across these age groups revealed no statistically significant differences ($p>0.05$). Therefore, age was not identified as a confounding variable in the anxiety reduction observed between visits. Statistical analyses of the mean ACDAS scores of the first and second visits are shown in Table 2. When the ages and genders of all participant children were compared, no significant difference was found in terms of ACDAS scores and physiological parameters ($p>0.05$). The mean ACDAS score obtained from the participants at the first visit before dental procedures was significantly higher compared to the second visit ($p<0.001$). After dental procedures, the mean ACDAS score was 25.23±1.82 and 23.07±1.98 at the first and second visits, respectively. The post-operative ACDAS score at the second visit was statistically significantly lower than the post-operative ACDAS score obtained at the first visit ($p<0.001$). When the pre- and post-operative mean ACDAS scores were compared at the first visit, the post-operative mean ACDAS score was statistically significantly lower than the pre-operative mean ACDAS score ($p<0.001$). Similar to these results, at the second visit, the post-procedure mean ACDAS score was significantly lower than the pre-procedure mean ACDAS score ($p<0.001$). Physiological parameters measured every 5 minutes at the first and second visits are shown in Table 3. There were no statistically significant differences between the oxygen saturation values obtained from the patients every 5 minutes at the first and second visits ($p>0.05$). When the heart rates measured at the first and second visits were compared, it was observed that the heart rate measured at the first visit was significantly higher than the second visit ($p<0.001$).

Table 1. Demographic analyses of the participants

Variables	
Gender, n (%)	
Female	115 (48)
Male	125 (52)
Total	240 (100)
Age, mean± SD	6.9±1.18

Abbreviation: SD, standart deviation.

Table 2. Analyses of the mean ACDAS scores of the first and second dental visits

	First Visit, (mean± SD)	Second Visit, (mean± SD)	*p-Value
Pre-operative ACDAS Score	27.52±1.96	25.01±1.21	**<0.001**
Post-operative ACDAS Score	25.23±1.82	23.07±1.98	**<0.001**

Abbreviation: SD, standard deviation
*p-two sample t-test value

Table 3. Comparison of physiological parameters obtained from the first and second dental visits

		First Visit, (mean± SD)	Second Visit, (mean± SD)	*p-Value
Oxygen Saturation	5th minute	98.52±1.96	98.23±1.82	0.083
	10th minute	98.01±1.21	98.07±1.98	0.091
	15th minute	98.61±1.38	98.81±1.21	0.073
Heart Rate	5th minute	99±3.11	93±3.78	**0.001**
	10th minute	96±4.01	90±4.21	**0.001**
	15th minute	92±3.89	87±4.39	**0.001**

Abbreviation: SD, standart deviation
*p-two sample t-test value

DISCUSSION

The participants included in this study were in the age range of 6-9 years. The inclusion of paediatric patients in this age group was based on previous studies on dental anxiety.[19-21]

These studies have reported that the level of dental anxiety in paediatric patients increases especially between the ages of 6-9 years. Children between the ages of 6-9 years show a rapid development in mental skills and are able to describe their experiences and emotions, both good and bad, more effectively.[19-22] Paediatric patients aged between 6 and 9 years do not have an effective cognitive ability to describe good or bad experiences and emotions.[23]

Wong-Baker FACES Pain Rating Scale was used in a study on the subject. This scale is not reliable enough because no validity and reliability study has been conducted in the Turkish population.[17] For this reason, in the present study, in order to increase the power of the results as a scale to evaluate the level of anxiety, the Turkish validity and reliability of the ACDAS, which has been tested, was selected.[12] This scale allows the assessment of children's emotional and physical behaviour to promote a better understanding of dental anxiety. Another major advantage of this scale is that it allows the child to answer the questions by choosing one of three facial figures: happy, sad and indifferent. In addition, the ACDAS as a scale assesses anxiety with responses from the child, the dentist and the parents or legal guardians.[7] One of the most outstanding advantages of the present study is the assessment of children's dental anxiety levels with a cognitive scale measuring anxiety according to the responses of children, parents and dentist.

The data obtained from the study showed that there was no statistically significant difference between consecutive dental visits in terms of gender and age. There was no statistically significant difference between the results of anxiety levels in all age ranges for both genders in the first and second visits of the patients. These findings of the present study are consistent with the studies of Rodrigues and Damle[24], Rayen et al.[25], Fux-Noy et al.[26] and Karaca[17].

The mean ACDAS scores and heart rates recorded during the first dental visit were significantly higher than those recorded during the second visit ($p<0.001$). The observed differences in anxiety levels and physiological parameters across both visits may be attributed to increased familiarity with the dental clinic environment, the pediatric dentist, and dental treatment procedures. The findings of the present study are consistent with previous research that characterizes dental anxiety as an adaptive process—particularly prominent in pediatric patients—that can diminish over time through appropriate behavioral interventions, environmental adaptation, and enhanced emotional regulation.[13–15] Furthermore, the outcomes align with those reported by Menezes Abreu et al.[27] and Karaca,[17] who also demonstrated that sequential dental visits contribute to a reduction in dental anxiety levels observed during dental treatments in children.

All participants received local anaesthesia to ensure procedural consistency and ethical pain management. While injection procedures may themselves contribute to anxiety, their uniform application across visits minimized confounding in comparative analyses.[28] Future studies incorporating a non-invasive control group or stratified anaesthesia protocols may offer further insight into the isolated impact of anaesthesia on dental anxiety.

The participants included in this study were patients who did not require emergency dental care. The structured scheduling of consecutive, non-emergency dental appointments served as a non-pharmacological behavioral management strategy, resulting in reduced anxiety levels and lower heart rates—an objective physiological marker of anxiety. This finding is particularly relevant for patients with no prior dental experience or those classified as potentially cooperative, as previously reported in the literature.[13–15,17,27] However, contrary to the present study's findings, in patients requiring emergency dental care, anxiety reduction has been reported to occur only after multiple consecutive treatment sessions.[29] This discrepancy may be due to the fact that these patients present with dental pain, which may exacerbate initial anxiety levels.

In contrast to these findings, the findings of the present study are inconsistent with the results of the study by Cademartori et al.[30] who reported that multiple dental visits resulted in increased levels of dental anxiety in children. These differences may be explained by the complex way in which dental treatment experiences affect children's dental anxiety.

The present study has several limitations:

- The homogenous nature of the study sample, which was confined to a single geographic and cultural region in Türkiye.
- The potential for selection bias, as participants were recruited from individuals presenting with non-emergency conditions and classified as potentially cooperative.
- The need for multicenter studies involving diverse populations to enhance external validity and generalizability of the findings.

CONCLUSION

The primary aim of this study was to investigate the effect of consecutive dental visits on dental anxiety in children. The present study emphasises that dental treatment experiences and acclimatisation of the child to the dental clinic environment may positively affect the dental anxiety levels of pediatric patients after consecutive dental visits.

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Epigenetics in Dentistry

Diş Hekimliğinde Epigenetik

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ABSTRACT

The concept of epigenetics is gaining increasing attention because it can cause changes in phenotype without altering the DNA sequence and to be found to have a very effective role in the emergence of phenotypic variations and many diseases, as well as genetic factors. In comparison to the studies on the relationship of epigenetics with other systemic diseases in the field of medicine, studies on the place of epigenetics in dentistry are very few. However, studies on the relationship between epigenetic mechanisms and oral diseases and their effects on dentistry practice continue to increase and become popular day by day. It is tought to have effects on tooth formation and development, orthodontics, periodontal diseases and caries formation. In this review, the functioning of epigenetic mechanisms is explained and it is aimed to discuss the relationship of these mechanisms with tooth development and oral diseases. The relationship of epigenetic mechanisms with caries, which one of the most important diseases of childhood, and its effects tooth formation were especially evaluated. At the same time, current epigenetic-related studies and promising new treatment approaches for dentistry practice are included.

Keywords: *Epigenetic, genetics, dentistry*

ÖZ

Epigenetik kavramı, DNA dizisini değişikliğe uğratmadan fenotipte değişikliklere sebep olabilmesi ve fenotipik varyasyonlar ve birçok hastalığın ortaya çıkmasında genetik faktörlerin yanında oldukça etkili bir rolü olduğunun ortaya çıkarılması sebebiyle artan bir ilgi görmektedir. Epigenetiğin diş hekimliğindeki yeri ile ilgili yapılmış araştırmalar, epigenetiğin tıp alanındaki diğer sistemik hastalıklarla olan ilişkisi hakkında yaplan araştırmalara göre oldukça az sayıdadır. Fakat epigenetik mekanizmalar ile oral hastalıkların ilişkisi ve bu etkilerin diş hekimliği pratiği üzerine olan yansımaları hakkında yapılan çalışmalar gün geçtikçe artmaya ve popülerleşmeye devam etmektedir. Diş oluşumu ve gelişimi, ortotodonti, periodontal hastalıklar ve çürük oluşumu üzerinde etkileri olduğu düşünülmektedir. Bu derleme çalışmasında, epigenetik mekanizmaların işleyişi anlatılmış ve bu mekanizmaların diş gelişimi ve oral hastalıklarla olan ilişkisi ele alınması amaçlanmıştır. Epigenetik mekanizmaların çocukluk çağının en önemli hastalıklarından olan çürükle olan ilişkisi ve diş oluşumu üzerinde olan etkileri özellikle değerlendirilmiştir. Aynı zamanda epigenetik ile ilgili güncel çalışmalara ve diş hekimliği pratiği için umut vaat eden yeni tedavi yaklaşımlarına yer verilmiştir.

Anahtar Kelimeler: *Epigenetik, genetik, diş hekimliği*

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Defining Epigenetics

Epigenetics refers to stable differences in gene expression that can be transmitted through meiotic and/or mitotic divisions without altering DNA sequences.[1] In other words, it refers to heritable phenotypic variations that are not caused by changes in the DNA sequence.[2] In its latest epigenomic reports (2009), the National Institutes of Health (NIH) of the United States defined epigenetics as encompassing both heritable changes in gene activity and expression (within the lineage of cells or individuals) and stable, long-term modifications in the transcriptional potential of a non-heritable cell.[3] Genetics, on the other hand, is defined as the study of heritable variations in gene function or activity that are directly related to changes in the DNA sequence. Such changes include deletions, point mutations, translocations, and insertions.[4] While genetic mutations are irreversible, epigenetic modifications can be reversible.[1] In summary, the key difference between genetics and epigenetics is that epigenetic modifications can be reversed using chemical agents. Additionally, the exact mechanisms of epigenetic inheritance have not yet been fully elucidated.[5]

Epigenetics seeks to explain how dramatic phenotypic differences arise in cells and organisms that share the same DNA. Various dietary and environmental factors can influence the extent and scope of epigenetic effects to varying degrees. Findings from epigenetic research have also revealed intriguing correlations between lifestyle choices and disease risk, further supporting this phenomenon.[6]

Mechanisms of Epigenetic Regulation

The three fundamental mechanisms of epigenetics have been identified as DNA methylation, post-translational modification of histone proteins, and RNA-based mechanisms.[3,6] These mechanisms are responsible for initiating and maintaining epigenetic silencing and the regulation of gene expression profiles. They also form the foundation for various cellular processes, including gene expression, cell differentiation, embryogenesis, X chromosome inactivation, and genomic imprinting.[7,8] Uncovering the relationships between these components has facilitated a faster and more insightful understanding of the regulation of gene expression. However, changes in an epigenetic profile can have a significant impact on cellular function, potentially leading to dysregulation of gene expression and, as a result, the development of epigenetic diseases.[9]

Dentistry and Epigenetics

Despite the numerous studies published on epigenetics in biology and medicine, research on the impact of epigenetics in dentistry is fewer and more limited. Due to its role in gene expression during development and its potential to influence susceptibility to oral diseases, epigenetics is expected to become increasingly popular in the field of dentistry.[10]

Although much of the research has focused on the effects of negative life experiences, beneficial developments can also induce changes in the epigenome. While epigenetics currently does not have a practical application in dentistry, it is believed to offer significant benefits in the future. For this reason, it is emphasized that all clinical practitioners should be aware of the fundamental principles.[11] It is anticipated that epigenetics could enable early intervention for the prevention of periodontitis, potentially preventing hypodontia and various dental anomalies related to tooth development. Epigenetics is also predicted to serve as a reliable screening tool for various dental anomalies, including enamel defects, and as a means to assess an individual's susceptibility to dental caries or periodontal disease more efficiently.[11,12]

Tooth Formation and Development (Odontogenesis)

This process is primarily controlled by the genome. However, it is well-known that epigenetic factors have an undeniable impact on tooth formation. Previous studies have shown that external factors, such as environmental influences leading to hypo- and hypermethylation of DNA, can cause differences in the teeth of monozygotic twins. Additionally, abnormal epigenetic regulation can disrupt the tooth formation process, leading to dental malformations and agenesis.[13]

Tooth formation is a complex process that involves numerous molecular events within the signaling pathways between epithelial and neural crest-derived mesenchymal tissues, which often overlap and occur in succession. [14,15] Environmental factors (such as radiation, chemotherapy, medications, etc.) and genetic mutations that influence any stage of the process can impair or halt tooth development. This, in turn, may lead to abnormalities in the number, shape, size, and structure of the teeth.[16]

Hypodontia

Hypodontia refers to a dental anomaly that includes a range of heterogeneous phenotypes, from anodontia (absence of all teeth) to oligodontia, which involves the congenital absence of one or more teeth, excluding third molars, typically involving more than six missing teeth. It can often present either as part of a syndrome or as an isolated feature unrelated to any syndrome. In most cases, it is reported that only one or two teeth are affected.[17] It is believed that the interactions between environmental, genetic, and epigenetic factors during tooth formation may contribute to abnormalities, but the exact mechanisms of formation are not yet fully understood. It is now well-established that DNA methylation plays a significant role in abnormal development, the emergence of defective phenotypes, and diseases, and it is thought that this process may also be involved in such conditions.[18]

Tooth Number and DNA Methylation

DNA methylation and histone modifications are two of the most common epigenetic modification processes.[19] In other words, they are the most common changes observed in DNA. They regulate chromatin inactivation, specific gene expression associated with embryonic growth, cell differentiation, and cancer progression, as well as determining the spatial control of cells and the timing of signaling interactions.[20] It has also been found that an enzyme called Histone Demethylase plays a role in regulating the differentiation of dental stem cells.[21]

Tooth development is influenced by interactions between neural crest and ectodermal epithelial tissues, and the pathogenesis of tooth agenesis can be determined by the interaction of multiple genes, as well as epigenetic and environmental factors.[22] In the post-genomic era, the epigenetic perspective and its effects have gained significant attention in recent years, with increasing evidence suggesting that epigenetic regulation plays a crucial role in phenotypic determination. Similar to the classic ‘epigenetic landscape’ metaphor proposed by Waddington, a 2016 study also suggested that changes in DNA methylation could lead to subtle differences in the spatial and temporal expression of local signals in odontogenic cells. In response to this, the number of teeth could be affected, and through an amplification mechanism, significant differences in the final appearance of odontogenesis could arise.[23]

According to Waddington, the local tissue-level interactions observed between cells during tooth formation are believed to be an example of an epigenetic event. Studies on monozygotic twin pairs with missing or extra teeth support the role of epigenetic factors in the tooth development.[24] For example, in a study of 24 monozygotic twin pairs with congenital absence of upper incisors or second premolars, it was found that in 21 of the pairs, the number and position of the affected teeth were inconsistent. Additionally, in 8 out of 9 monozygotic twins, the number of extra teeth was also reported to be inconsistent.[25]

Another study conducted on nine Japanese individuals with cleidocranial dysplasia syndrome revealed significant variability in the expression of supernumerary teeth among individuals with the same genetic mutation. Additionally, the study demonstrated the presence of discordance in one pair of monozygotic twins.[26] These findings support the view that supernumerary tooth formation is influenced not only by genetic factors but also by environmental and epigenetic factors.[27]

Various factors can influence both the establishment of methylation and the maintenance of this methylation process over time. The factors studied and hypothesized so far include age, ethnicity, dietary characteristics, chemical exposure, and smoking.[25,27,28]

Periodontology

Cytokines are among the biomolecules that trigger the inflammatory response and are generally classified as pro-inflammatory and anti-inflammatory cytokines. Epigenetic modifications in genes encoding cytokines have been shown to alter cytokine expression, potentially leading to either pro-inflammatory or anti-inflammatory responses. Additionally, studies have demonstrated a relationship between epigenetic variations in genes responsible for encoding pro-inflammatory cytokines and periodontitis.[29] Epigenetic modifications in pro-inflammatory mediators in periodontitis are associated not only with oral bacteria but also with various environmental factors such as smoking and diet.[30,31] A relationship between DNA methylation, pro-inflammatory mediators, and aggressive periodontitis has been demonstrated.[32]

Orthodontics

Current studies in the periodontal field investigate the effects of known epigenetic mechanisms on specific genes, whereas orthodontic literature focuses on the broader scope of epigenetics, classifying environmental factors such as condylar forces that influence jaw growth and remodeling. From this perspective, environmental factors are not considered influences on the genome itself but rather external elements. Forces acting on the jaw can induce epigenetic changes that affect gene expression. However, orthodontic literature has yet to fully elucidate which specific epigenetic modifications influence which genes.[10]

Profitt highlights that a fundamental difference in craniofacial growth theory lies in the location where gene regulation is expressed.[33] For example, if bone is considered the primary determinant of craniofacial growth, genetic control is assumed to occur at the bone level. If cartilage is regarded as the key determinant, genetic regulation is thought to take place at the cartilage level. As explained in Moss’s Functional Matrix Hypothesis, if the matrix of soft tissues surrounding skeletal elements is considered the main determinant of bone development, then genetic control is believed to occur outside the skeletal system.[34]

Carlson has stated that he believes the genes regulating craniofacial development are switched on and off at critical time points. He argues that the key factor is not the control of morphogenesis by intrinsic factors within the genome, but rather the complex interactions between distant extrinsic factors in the body and environment, as well as the cells and tissues that trigger or inhibit gene expression influencing postnatal growth. These interactions, in turn, affect developmental processes and the rate of response to clinical treatment procedures.[35] Carlson suggested that, in the future, orthodontists might commonly use molecular kits to diagnose growth-related issues, assess each patient's developmental stage, and determine the presence or absence of key polymorphisms in growth factors and signaling molecules.[10,35]

Amelogenesis (Enamel Formation)

It is stated that tooth enamel is the hardest tissue known in the human body and develops from the oral epithelium. More than 95% of its volume is composed of large and organized hydroxyapatite crystals, making it a highly mineralized tissue. The formation of this highly organized and extraordinary structure is believed to be controlled by ameloblasts through the interaction of various organic matrix components containing enzymes such as tuftelin, enamelin, amelogenin, dentin sialophosphoprotein, matrix metalloproteinase 20, ameloblastin, amelotin, and kallikrein 4.[36] Ameloblasts, which are responsible for the production of enamel, undergo numerous differentiation processes during enamel formation. In the continuously erupting incisors, Sox2-positive cell populations are located in the labioservical loops of the enamel organs and contribute to the formation of all epithelial cells of the tooth, including ameloblasts, the stratum intermedium, stellate reticulum, and the epithelial cell remnants of the Malassez cells.[37,38]

Enamel formation consists of several developmental stages that are tightly regulated and controlled by interactions between the dental epithelium and mesenchymal tissue. Small alterations in these complex biochemical and physiological developmental processes can lead to significant enamel defects in terms of shape, color, and structure. It has been found that regulations in microRNA (miRNA), DNA methylation, and chromatin modifications act as key regulatory mechanisms in tooth development. The increasing number of studies on the epigenetic regulations involved in enamel development offers an exciting opportunity to identify new etiological factors related to enamel and explore potential therapeutic approaches.[39]

Immunohistochemical studies have shown that DNA Methyltransferase 1 (Dnmt1) is highly expressed in immature dental epithelial cells, with expression levels decreasing in later developmental stages, consistent with quantitative data published in a 2015 study. Additionally, de novo DNA methyltransferases Dnmt3a, Dnmt3b, and the TET family genes (with the exception of Tet1, which is highly expressed in immature dental epithelial cells) have been found to be predominantly expressed. The obtained spot staining data and immunohistochemical results suggest that dynamic changes in DNA methylation and hydroxymethylation occur during enamel formation. These findings indicate that Dnmt1 and Tet1 may be important epigenetic factors involved in enamel development.[40]

In the same study, immunohistochemical analysis of Dnmt1 in the developing mandibular incisors of 10-day-old mice revealed the presence of Dnmt1 in the cervical loop epithelium and surrounding pulp mesenchyme, with Dnmt1-positive cells disappearing as tooth development progressed. The stellate reticulum, outer enamel epithelium, other cells in the papillary layer, and stratum intermedium were also reported to stain exclusively with Dnmt1. Therefore, it is suggested that Dnmt1 may be associated with the undifferentiated state of dental epithelial cells. In summary, Dnmt and TET enzyme families appear to be key players in this epigenetic reprogramming. Consequently, it is hypothesized that changes in the chromatin structure of dental epithelial cells occur as DNA methylation progresses. This information is believed to be valuable in understanding the epigenetic events during enamel formation.[40]

Figure 1: Amelogenesis imperfecta can be clinically classified into various subtypes depending on the type of defect and the stage of enamel development at which it occurs. a-b-c-d: hypoplastic type, e-f: hypocalcified type, g-h: hypomature type.[36]

Enamel Defects

Amelogenesis Imperfecta (AI) is a congenital disorder that can affect the process of enamel formation and mineralization. In AI, the enamel of the teeth may present as hypomature (normal enamel thickness but colorless and softer than normal enamel), hypocalcified (normal enamel thickness but extremely weak), hypoplastic (thin enamel), or combinations of these variations.[41]

The normal development of dental enamel occurs in three stages. In the first stage, the matrix of the enamel is formed. In the second stage, the matrix undergoes the process of mineralization, and in the third stage, crystal growth leads to maturation. Enamel formation in permanent incisors begins between the ages of 3 and 12 months and is completed by the age of 4 to 7 years.[37,38]

The presence of enamel defects is closely associated with events occurring during the critical stages of enamel formation and mineralization. Enamel defects are linked to a wide range of causes, including genetic and epigenetic factors, as well as systemic, local, and environmental influences. Perinatal or prenatal conditions, low birth weight, routine antibiotic use, malnutrition, systemic diseases such as celiac disease, and respiratory disorders such as asthma can be associated with enamel defects[39]

Environmental factors known to affect enamel formation include fever, hypoxia, malnutrition, and exposure to various toxic substances that adversely affect enamel cells during development. Other influencing factors include environmental pollutants and socioeconomic status. During the time when cells are secreting the enamel, these external factors can interfere with the formation of enamel.[39]

Molar Incisor Hypomineralization (MIH) is another clinical condition that demonstrates the potential impact of environmental factors on enamel formation. In the presence of a genetic predisposition, medical issues that arise during various prenatal, perinatal, and postnatal periods, the use of certain medications in early life, and early exposure to fluoride and environmental pollutants (such as dioxins, polychlorinated biphenyls or PCBs) can lead to hypomineralization of the dental enamel.[40]

Respiratory diseases such as asthma can make ameloblasts highly sensitive to oxygen supply. The use of toothpaste containing mint can also lead to shortness of breath, increasing bronchospasm and potentially causing ameloblastic anoxia. The prevalence of enamel hypoplasia in children with bronchial asthma is significantly higher compared to children without the disease.[42] It has been found that the prevalence of enamel defects in permanent teeth among Brazilian children with asthma is 11 times higher compared to normal children.[43,44] Respiratory diseases like these have been associated with limited opacification and developmental defects observed in the enamel structure of the first permanent molars.[38]

Figure 2: Enamel hypoplasia and defects in the anterior and posterior teeth of a patient with a history of asthma medication use.[38]

Dentin Formation and Defects

Dentin formation is a highly organized and regulated process that involves multiple cellular and extracellular components. Interactions between various factors occur during the differentiation and morphogenesis stages; however, they can also take place during the mineralization phase of the extracellular matrix in dentin. The subsequent mineralization process in dentin formation shows some similarities with osteogenesis and cementogenesis.[45]

The dentinogenesis process, including odontoblast differentiation, is stated to be based on the coordinated expression of regulatory genes such as transcription factors and growth factors. Gene expression is influenced by epigenetic conditions such as DNA methylation and histone modifications. DNA methylation has been found to regulate odontoblast differentiation. However, the effects of histone modifications on the control of odontoblast differentiation are not yet fully understood. Nevertheless, published in vitro studies confirm that histone acetylation plays a role in dentin formation.[46]

A study published in 2020 investigated the expression patterns of histone proteins, specifically histone 3 lysine 9 (H3K9ac) and H3K27ac, during dentinogenesis and odontoblast differentiation. Using mandibular incisors from live mice, the study showed that H3K27ac and H3K9ac were up-regulated during odontoblast and dentinogenesis differentiation. The research also observed that histone acetyltransferases (HATs), p300, and histone deacetylase 3 (HDAC3) exhibited a distinct expression pattern during differentiation. Furthermore, it was confirmed that histone acetyltransferases, p300, and HDAC3 modulate histone acetylation and regulate odontoblast differentiation. The coordinated expression of p300 and HDAC3 was found to be up-regulated by histone acetylation in order to regulate dentin formation.[46]

Behavior Management

It has long been known that a mother's fear of the dentist is a significant factor in some children's anxiety and issues with accepting dental care.[47] Evidence showing that fear is transmitted across generations at behavioral, neuro-anatomical, and epigenetic levels suggests that dental anxiety likely has deeper causes, as some anxious children are more likely to adopt behaviors learned from their parents. This implies that for certain children, treatment should aim not only at addressing learned fears but also at identifying epigenetic changes. According to Yehuda and colleagues' research, psychotherapy can create an 'environmental regulation' model that can alter epigenetic states. The study demonstrated that psychotherapy affects the activity of stress hormones and alters the methylation of the FKBP5 gene in a specific region of DNA. Additionally, the study found that methylation of the GR gene (NR3C1) at the exon 1F promoter influenced treatment outcomes. These findings suggest that epigenetic testing could be developed to predict which patients with behavioral issues will respond to psychotherapy, and successful treatment outcomes could be associated with epigenetic changes. [10,48]

Childhood Caries and Epigenetics

Despite significant progress over the years in caries management, including the protective effects of fluoride, increased oral health activities, comprehensive health education, and advancements in treatment options, dental caries remains the most prevalent childhood disease.[49] There is direct evidence suggesting that genetic components play a role in the etiology of dental caries, but very little is known about the specific mechanisms involved.[50,51] There are numerous genes related to hereditary changes that affect the composition and structure of enamel, as well as genes involved in the genetic regulation of salivary gland functions and sugar metabolism. However, it cannot be said that there is a single host gene directly responsible for initiating or regulating dental caries progression.[19,52]

Epigenetics is a biological process that interacts with gene sequences (or DNA) to modify gene expression through molecular mechanisms. Events occurring in the early stages of life can influence the disease risk in the developing fetus.[53] Although few studies have explored this connection, epigenetic changes may increase the risk of dental caries by altering the expression of genes related to enamel formation, taste, immunity, and saliva secretion, likely as a response to adverse events during pregnancy and early life.[19]

Maternal obesity has been linked to obesity in childhood. Shared nutrition and lifestyle choices are significant factors in this relationship; however, 'fetal programming' can also contribute to this condition due to its epigenetic effects on the intrauterine environment.[54] However, despite numerous studies showing a correlation, the link between obesity and dental caries remains a controversial topic.[55]

A birth cohort study involving 27 male twins was conducted in 2021 to investigate the relationship between DNA methylation in leukocytes obtained from umbilical cord blood at birth and dental caries experience and dental enamel hypomineralization at age 6. The 6-year dental examination assessed (i) 'any caries' (untreated and treated caries), (ii) 'advanced caries' (untreated, advanced caries and/or previous treatment), and (iii) the presence/absence of hypomineralized second primary molars (HSPM). The study also considered whether the twins were monozygotic or dizygotic. Differentially methylated regions (DMR) and CpGs (DMCpG) were examined. The results showed that 19 children had 'no caries' while 15 had 'advanced' caries and 18 had HSPM. DMCpGs were not associated with 'any caries' but 16 and 19 DMCpG genes were found to be associated with 'progressive caries' and HSPM, respectively. DMR was found to be associated with all three outcomes. The genes associated with these analyses include PBX1, ACAT2, LTBP3, and DDR1, which have been linked to dental tissue development in genetic studies. These findings suggest that epigenetic differences present at birth may be associated with dental health at age 6, and these differences may serve as an important biomarker of early dental health effects.[56]

Current Approaches Related to Epigenetics

Epigenetic changes involve various histone and DNA modifications that can lead to significant phenotypic alterations. These epigenetic events are inherently reversible. In response to secondary environmental changes, epigenetic modifications can progress further, be reversed, and even completely restore the substrate to its original state, demonstrating a capacity for full reversal.[57]

Recent studies have shown that histone modifications are associated with the methylation of CpG nucleotides within DNA, thereby linking a wide range of epigenetic modifications and regulatory mechanisms.[58] This connection creates new scenarios in which an 'epigenetic code' can control the expression of specific gene sequences, essentially acting as an 'on/off' switch for numerous cellular events. As epigenetic drugs continue to be developed and become more refined and specific, greater control over epigenetic switches will be possible. If an appropriate therapeutic combination can be developed, it may be possible to reverse disease phenotypes, especially when drugs are applied during the early stages of the disease. For example, the idea that epigenetic drugs could eliminate resistant cancer cells while preventing the formation of cancer precursor cells is being explored.[59]

Epigenetic modifications are responsible for differentiating the expression of our genetic material in terms of time and space. This helps explain why, despite all our cells having the same DNA, such a wide variety of cell types can form different tissues and perform distinct functions. Most studies focus on the effects of negative life experiences, but positive events can also induce changes in the epigenome, some of which can be reversed.[48]

Through research on epigenetics, several key factors that may affect oral health, including diet, smoking, environment, bacteria, and inflammation, have been identified as potentially influencing immune responses. Future clinical studies conducted by dentists and dental hygienists will provide insights into whether and how these factors affect oral health.[60]

The potential link between epigenetics and oral health will also provide answers as to why some patients do not respond to treatment. Furthermore, studies on genetic and local factors in immune responses can be used to identify and diagnose individuals at risk of developing disease. Since epigenetic changes are reversible, it should not be overlooked that these changes can be altered by environmental factors, potentially leading to disease. From this perspective, reversing epigenetic changes and preventing or halting the progression of disease will become possible.[60]

It is now known that various nutritional factors, such as folic acid, vitamin B12, and vitamin A, can cause changes in epigenetic modifications. Additionally, it has been stated that smoking can lead to changes in DNA through effects such as hypomethylation and hypermethylation. Therefore, it is emphasized that certain exogenous factors, including diet, smoking, environment, bacteria, inflammation, and age, can trigger epigenetic changes that affect oral health.[60]

Current Diagnostic and Therapeutic Approaches in the Field of Periodontology

Current international consortia are increasingly emphasizing the importance of the relationship between general health and oral health. There is a growing trend of epigenetic research in dentistry, and numerous epigenetic studies have begun in the field of periodontology. In addition to microbial communities, one of the environmental factors, interactions between pathogens and the host also play a significant role in the control of periodontal diseases. Since genetic factors are insufficient to explain the variation in host responses, epigenetic effects have been suggested to explain these differences. While genetic factors are undoubtedly crucial in the development of the disease, they can become risk factors when the body is triggered by something foreign. However, epigenetic changes can alter gene expression patterns by inducing different host responses without changing the DNA sequence. Therefore, research has focused on controlling disease susceptibility to infections through gene expression, immune responses, and epigenetic factors. Additionally, studies are ongoing to discover new epigenetic biomarkers for diagnosis, prognosis, and treatment methods.[61]

Various epidemiological findings demonstrate a close relationship between non-communicable diseases and oral diseases. Additionally, there is a possibility of overlap in common risk factors between systemic and oral diseases and epigenetics. In parallel with global research, further investigation into the functional and regulatory factors associated with periodontal health status and systemic diseases will help identify new biological mechanisms, thus aiding in the development of diagnostic biomarkers and therapeutic strategies to support both oral and systemic health.[62]

Current Diagnostic and Treatment Approaches Related to Pulp Inflammation

There are studies investigating the use of circulating miRNAs as biomarkers for several common inflammatory diseases (e.g., asthma, inflammatory bowel disease, rheumatoid arthritis).[63] Recent research has focused on the use of proteins as diagnostic biomarkers. In particular, the increased stability of miRNAs in the circulatory system offers enhanced diagnostic advantages, making them promising biomarkers for the diagnosis of pulpal conditions. Moreover, the recent increase in knowledge about miRNA biomarkers has introduced numerous new possibilities for the more accurate diagnosis of pulp diseases.[64]

The ability to isolate miRNAs from inflamed dental pulp samples or point-of-care diagnostic kits could enable accurate diagnosis and the selection of appropriate treatment procedures. This advancement has the potential to eliminate many of the clinical prediction methods currently used in dentistry. Additionally, the application of miRNA-based therapeutic dental materials to exposed pulp tissue is being considered to stimulate the differentiation of dental pulp stem cells into odontoblast-like cells and facilitate the initiation of dental pulp repair processes. Research on approaches involving non-coding RNA (ncRNA) is relatively new, and its integration into clinical practice will inevitably take time. These studies are creating exciting new research avenues in regenerative endodontics and are expected to be a focal point for future investigations.[64]

CONCLUSION

Epigenetic approaches reveal that the development of systemic diseases, oral diseases, and various phenotypic variations is not solely influenced by genetic factors. Numerous studies have shown that various environmental factors, diet, and other exogenous factors can cause changes in epigenetic modifications.[61] At the same time, many studies have demonstrated the role of epigenetic modifications in enamel formation, dentin formation, and related defects.[39,46]

The research is important because it shows that negative experiences, such as fear of the dentist, can be transmitted to the next generation through epigenetic inheritance, which is also relevant for clinical practices in dentistry.[48] Currently, the number of studies examining epigenetic approaches in dentistry remains insufficient. In the field of dentistry, further research is needed for epigenetic mechanisms to provide practical benefits to dentists in diagnosis, treatment, and clinical applications.

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Endodontic Treatment Approaches of Immature Permanent Teeth with Necrotic Pulp

Kök Gelişimi Tamamlanmamış Nekrotik Pulpalı Daimi Dişlerde Endodontik Tedavi Yaklaşımları

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ABSTRACT

Pulp necrosis in immature permanent teeth results in the cessation of root development. In such teeth, pulp necrosis is commonly attributed to factors such as caries or trauma. Endodontic treatment of immature teeth with open apices presents various clinical challenges, particularly concerning root canal preparation and obturation, which require meticulous attention. Treatment options for immature teeth include conventional root canal therapy, apexification, creation of an apical barrier using mineral trioxide aggregate (MTA), and regenerative endodontic procedures. Each of these treatment approaches has its own advantages and disadvantages. This review provides a comprehensive overview of current treatment options for the clinical management of immature permanent teeth with open apices.

Keywords: *Apexification, Calcium hydroxide, Mineral trioxide aggregate, Regenerative endodontics, Necrotic immature permanent tooth*

ÖZ

Gelişimi tamamlanmamış daimi dişlerde pulpa nekrozu, kök gelişiminin durmasına neden olmaktadır. Bu tür dişlerde pulpa nekrozunun gelişiminde genellikle çürükler veya travmalar gibi etmenler rol oynamaktadır. Kök gelişimi tamamlanmamış açık apeksli dişlerin kök kanal tedavileri, klinik yönetim açısından çeşitli zorluklar içermektedir. Özellikle kanal preparasyonu ve dolgusu bu tür vakalarda özel dikkat gerektirmektedir. Bu tip dişlerde geleneksel kök kanal tedavisi, apeksifikasyon, mineral trioksit agregat (MTA) ile apikal bariyer oluşturma ve rejeneratif endodontik prosedürler gibi farklı tedavi seçenekleri uygulanabilmektedir. Bu tedavi yaklaşımlarının her birinin avantajları ve dezavantajları bulunmaktadır. Bu derlemede, kök gelişimi tamamlanmamış açık apeksli daimi dişlerin klinik yönetiminde güncel tedavi seçenekleri ayrıntılı bir şekilde ele alınmaktadır.

Anahtar Kelimeler: *Apeksifikasyon, Kalsiyum hidroksid, Mineral trioksid agregat, Rejeneratif Endodonti, Nekrotik immatür daimi diş*

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Root canal treatment aims to eliminate infected tissue and debris, shape and disinfect root canals, and achieve a three-dimensional, hermetic seal. Although most endodontic cases are predictable and manageable, treating necrotic, immature permanent teeth presents significant clinical challenges due to incomplete root development and inadequate crown-to-root ratios.[1] The complexities arise from thin, divergent dentin walls and an open apex, which hinder effective canal preparation and compromise apical sealing.[1] Additionally, these teeth are more susceptible to root fractures under occlusal forces due to fragile dentin walls.[1]

This review explores the etiologies of pulp necrosis in immature permanent teeth, including trauma, dental caries, and anomalies.[2] It examines evolving treatment modalities, ranging from traditional apexification to modern regenerative endodontic procedures. The review aims to provide updated insights into the clinical management of these challenging cases.

Etiology of Pulp Necrosis in Immature Permanent Teeth

Pulp necrosis in immature permanent teeth disrupts the natural process of root development, leaving the tooth structurally compromised. The two primary causes of pulp necrosis in these cases are caries and trauma.[3]

- *Caries***:** is a complex, multifactorial disease that triggers inflammation in the pulp tissue through bacterial invasion and the release of harmful by-products.[3] If left untreated, this inflammatory response can progress to pulp necrosis. The condition is exacerbated by the inability of immature teeth to mount an effective defense due to their underdeveloped dentinal walls.
- *Trauma***:** Traumatic injuries, occurring between the ages of 8 and 10, are particularly significant because root development of permanent teeth is still incomplete.[1, 3] During this critical developmental phase, damage to the vascular supply disrupts pulpal circulation. Without sufficient revascularization, the pulp tissue becomes necrotic, leading to a complete cessation of root development.

If pulp pathology affects teeth with open apices, root maturation is abruptly halted. Consequently, these teeth present wide canals, fragile dentin walls, and open apices—sometimes exhibiting a ‘blunderbuss’ appearance. This unique morphology complicates biomechanical preparation and hinders effective apical closure.[4]

Types of Open Apices

Open apices can be categorized into two distinct types: blunderbuss and non-blunderbuss.[4]

- Blunderbuss Apices: are characterized by divergent canal walls that widen buccolingually, creating a funnel-shaped apex that is broader than the coronal part of the canal. According to the American Association of Endodontists (AAE) Glossary of Endodontic Terms, a blunderbuss canal is defined as an underdeveloped root with an apical diameter that exceeds the coronal diameter.[5] This anatomical configuration presents significant challenges in achieving an apical seal due to its irregular shape and size.
- Non-Blunderbuss Apices: In contrast, non-blunderbuss apices feature canal walls that are either parallel or subtly tapered. The apex remains wide but assumes a more regular shape, such as cylindrical, conical, or convergent.[4] These apices are generally easier to manage during endodontic treatment because of their more predictable morphology.

Cvek categorized root development into five stages based on the width of the apical foramen and root length.[6] This classification provides a systematic approach to assess the maturation of permanent teeth and guides endodontic treatment decisions, particularly in immature teeth with open apices.

Five Stages of Root Development

Stage I: Teeth with wide, divergent apical opening and have less than half of the expected final root length. These teeth exhibit minimal root elongation and significant structural vulnerability due to thin dentinal walls.

Stage II: Teeth with wide, divergent apical opening and have approximately half of the expected final root length. While slightly more developed than Stage I, these teeth still lack sufficient root length and thickness to ensure structural stability.

Stage III: Teeth with wide, divergent apical opening and have about two-thirds of the expected final root length. Although closer to full maturation, the apical closure remains incomplete, necessitating careful endodontic management.

Stage IV: Teeth with a wide, open apical foramen and nearly complete root length. At this stage, the root is almost fully developed, with the apical foramen remaining open but narrowing as maturation continues.

Stage V: Teeth with a closed apical foramen and fully developed root length. These teeth exhibit complete root maturation, with thick dentinal walls and a closed apex, providing optimal structural integrity and resistance to fracture.

Root Development and Potential Complications

Root development begins after the formation of enamel and dentin, reaches the cementoenamel junction (CEJ) and continues for 3 to 4 years following tooth eruption.[7] During this critical period, the Hertwig's epithelial root sheath directs the elongation and maturation of the root. However, if this structure is damaged—due to trauma, caries, or other pathological conditions—pulp necrosis may occur, potentially halting root apex development. As a result, the affected tooth remains immature, presenting a blunderbuss canal anatomy characterized by a wide apical opening and thin dentinal walls.[1] This unique morphology poses significant challenges for endodontic treatment, particularly in achieving effective apical sealing and preventing root fractures.[1]

An open apex is commonly associated with young permanent teeth that experience trauma during the early stages of root development.[8] Such injuries can disrupt the vascular supply to the pulp, leading to necrosis and premature cessation of root formation. Consequently, the tooth remains underdeveloped with wide canals and fragile walls, increasing its susceptibility to fracture and complicating endodontic management.[8] However, an open apex is not exclusively linked to immature teeth. In some cases, it can also occur in fully developed teeth due to specific pathological conditions, including:

- *External Inflammatory Root Resorption:* Resulting from chronic periapical inflammation or trauma.
- *Iatrogenic Over-Preparation:* Excessive instrumentation during endodontic procedures may weaken the apical region.
- *Root Resection:* Surgical removal of the apical portion of the root. [9-11]

These conditions disrupt the apical closure, leading to an open apex that requires specialized endodontic techniques to achieve effective sealing and long-term clinical success.

Clinical Challenges in Endodontic Treatment of Teeth with Open Apices

The endodontic management of teeth with open apices involves several complex clinical challenges due to their unique anatomical structure. These challenges require meticulous planning and precise execution to ensure successful treatment outcomes.

1. Determination of Working Length

Accurately establishing the working length in teeth with open apices is particularly challenging due to the absence of a natural apical constriction. If the working length is inaccurately determined, there is a significant risk of over-instrumentation, leading to the extrusion of irrigation solutions, intracanal medicaments, or root canal filling materials beyond the apex. This accidental extrusion may cause persistent periapical inflammation and increase the likelihood of postoperative pain.[12]

To minimize the risk of over-preparation, it is recommended to use electronic apex locators in conjunction with radiographic evaluation to determine the precise working length.[13] The combined use of these diagnostic tools enhances accuracy, reduces the risk of overfilling, and ensures adequate cleaning and shaping without compromising the periapical tissues.

2. Cleaning and Shaping of Root Canals

Teeth with open apices are inherently more susceptible to root fractures due to their thin and fragile dentinal walls. This structural weakness presents a significant challenge when performing conventional cleaning and shaping procedures, as:[14]

- Excessive instrumentation can further weaken the dentinal walls, increasing the risk of vertical root fractures.
- Mechanical preparation is particularly challenging, as it requires delicate handling to avoid unintentional damage to the already fragile root structure.[14]

To address these challenges, clinicians should adopt **minimally invasive cleaning and shaping techniques** that prioritize **chemical disinfection** over aggressive mechanical instrumentation. This approach may reduce the risk of fracture while ensuring thorough debridement of the root canal system.

3. Obturation of Root Canals

The blunderbuss canal anatomy frequently observed in immature teeth poses considerable difficulties in achieving an optimal three-dimensional obturation. Despite these challenges, adequate root canal obturation remains a critical step in the endodontic treatment process. In fact, studies indicate that approximately 60% of endodontic failures are directly linked to inadequate root canal filling.[15]

Treatment Options for Immature, Non-vital Permanent Teeth with Open Apices

The primary objective of treating immature, non-vital permanent teeth with open apices is to achieve healing of periapical pathology, resolution of clinical symptoms, continued root development with apical closure, and restoration of functional pulp vitality.[16] Preserving immature permanent teeth is crucial for both functional and aesthetic reasons. These teeth play a vital role in:

- *Maintaining Occlusal Function:* Ensuring proper alignment and function within the dental arch.

- *Supporting Facial Aesthetics:* Contributing to facial profile and symmetry, particularly during craniofacial growth.

Furthermore, implant placement is generally contraindicated in young patients until craniofacial growth is complete.[16] Therefore, retaining immature permanent teeth becomes even more critical to prevent space loss and maintain alveolar bone integrity.

Due to the thin and fragile dentin walls characteristic of immature teeth, conventional root canal cleaning and shaping techniques may further weaken the root structure. Therefore, the disinfection of infected root canals in these cases primarily relies on irrigation solutions and intracanal medicaments. [17]

Evolution of Treatment Approaches for Immature, Infected Permanent Teeth

In the past, the treatment of immature, infected permanent teeth involved techniques that focused on achieving adequate obturation without promoting continued root development. These conventional methods included the placement of large gutta-percha fillings or the roll-cone gutta-percha technique, with the root canal filling materials positioned short of the apex, or by performing periapical surgery. [18]

However, these traditional approaches were limited by the absence of an apical barrier, which compromised the quality of the apical seal and increased the risk of microleakage.[13] As a result, these techniques have been largely replaced by more advanced methods that provide predictable outcomes and improved long-term success.[13] Currently, there are three main treatment modalities for immature permanent teeth with infected root canal systems and open apices:

- Apexification with calcium hydroxide ($Ca(OH)_2$),
- Apical barrier formation using mineral trioxide aggregate (MTA), and
- Regenerative endodontic procedures.

Apexification

Apexification is defined as “the process of inducing a calcified barrier in the apical region of an immature root with a necrotic pulp or facilitating the continued apical development of an incompletely formed root.”[5] This procedure involves biomechanical canal debridement beyond the apex, followed by the placement of a biocompatible material to induce a hard tissue barrier and facilitate root canal obturation by forming an apical barrier. [19,20]

Calcium hydroxide remains the gold standard for apexification due to its potent antibacterial properties and ability to stimulate the formation of an apical hard tissue barrier.[20-22] This material plays a crucial role in endodontics by creating an environment that supports mineral deposition and prevents microbial proliferation within the root canal system. The apical hard tissue barrier formed by calcium hydroxide is commonly described as a cap, bridge, or inward-growing wedge. It consists of multiple layers of necrotic and mineralized tissues, which contribute to its structural integrity. However, this barrier is often porous and incomplete, making it susceptible to microleakage. Histological studies reveal that it may contain cementum, dentin, bone, or a specialized form of mineralized tissue referred to as ‘osteodentin. [19,20]

Research suggests that in immature teeth with infected pulp and a compromised Hertwig’s epithelial root sheath, viable cementoblasts and undifferentiated fibroblasts within the periapical tissues and periodontal ligament play a crucial role in apexification.[19] These cells are thought to differentiate and contribute to the formation of the apical hard tissue barrier, facilitating root development despite the loss of normal Hertwig's epithelial function.[19] Apexification with $Ca(OH)_2$ has been extensively studied in endodontics and remains a widely accepted and reliable treatment approach.[18] It has demonstrated consistent success in inducing mineralized tissue deposition, creating an effective apical barrier to prevent further resorption and reinfection. However, treatment duration and variability in barrier integrity remain key considerations when selecting this approach.[18] Table 1 outlines the indications and contraindications for apexification, highlighting the clinical scenarios where this technique is most beneficial and where alternative strategies may be preferable.

Table 1: Criteria to Consider When Determining the Indication for Apexification Treatment.

Indications for Apexification	Contraindications for Apexification
Necrotic/infected pulp in an immature tooth **(+)**	Presence of purulent drainage from canals
No spontaneous pain, uncontrolled bleeding, or percussion sensitivity	Presence of persistent long-term pain
Root length ≥ ½ of its expected final length **(+)**	Presence of extremely short root(s)
No evidence of horizontal or vertical root fracture	Periodontal damage extending near the gingival margin
No radiographic signs of ankylosis	Presence of vital pulp tissue
Tooth is restorable **(+)**	
Presence of periapical radiolucency	

Mechanism of Action and Limitations of Calcium Hydroxide in Apexification

The biological effects of $Ca(OH)_2$ are primarily attributed to the dissociation of calcium and hydroxyl ions, which significantly influence the periapical environment. Upon application, $Ca(OH)_2$ elevates the local pH to approximately 12.5, creating an alkaline environment that plays a critical role in endodontic healing. [23]

Its high alkalinity neutralizes lactic acid produced by osteoclasts in the periapical region, effectively inhibiting demineralization and halting further bone resorption.[24] Moreover, $Ca(OH)_2$ stimulates alkaline phosphatase activity, which is essential for the initiation and regulation of hard tissue formation. Additionally, the gradual release of calcium ions has been shown to activate growth factors necessary for mineralization and tissue repair. [25]

While calcium hydroxide remains a cornerstone in apexification, its use presents several notable limitations that must be considered in clinical decision-making:

- Limited Root Development: The hard tissue barrier induced by $Ca(OH)_2$ forms only at the apical region, leaving the root canal walls thin and short. As a result, no further root elongation or structural reinforcement occurs, potentially compromising long-term tooth viability.[19-21]
- Impact on Regenerative Potential: Due to its high pH, $Ca(OH)_2$ has been suggested to damage cells with regenerative capacity that might otherwise contribute to continued root development or pulp regeneration.[19]
- Structural Weakening of Dentin: Prolonged exposure to calcium hydroxide has been associated with increased dentin brittleness, primarily due to its hygroscopic and proteolytic effects. This structural degradation raises the risk of root fractures, with studies indicating a 50% reduction in fracture resistance after one year of intracanal $Ca(OH)_2$ application. [19,20,26,28]
- Extended Treatment Duration: One of the major drawbacks of calcium hydroxide apexification is the need for frequent medicament changes and an often-prolonged treatment course. The duration varies depending on factors such as patient age, periradicular radiolucency, and apical width.[20,29] Reports indicate that the time required for apical barrier formation ranges between 3 and 24 months, with an average duration of 12 months.[22,26]

The prolonged treatment duration and multiple required appointments pose significant challenges in clinical practice. Extended therapy not only reduces patient compliance but also complicates follow-up care, making long-term monitoring more difficult. Additionally, prolonged exposure to potential coronal leakage heightens the risk of bacterial reinfection, potentially compromising treatment success.[20,26]

Given these limitations, MTA has emerged as a more favourable alternative to calcium hydroxide in apexification. Its superior sealing ability, biocompatibility, and faster barrier formation have led to its increasing adoption in endodontic practice.[30, 31] MTA addresses many of the drawbacks associated with calcium hydroxide, offering a more predictable and efficient solution for managing immature necrotic teeth.

Apical Barrier Technique

The apical barrier technique is defined as the nonsurgical condensation of a biocompatible material at the apical end of the root canal.[30] The primary objective of this method is to establish an artificial apical plug, enabling predictable root canal obturation without relying on the induction of natural apical closure. By providing a stable apical seal, this approach minimizes the risk of extrusion and enhances long-term treatment success. Developed to address the limitations of traditional calcium hydroxide apexification, the apical barrier technique has gained widespread acceptance, particularly with the use of MTA as the preferred material. MTA's excellent biocompatibility, sealing properties, and ability to stimulate hard tissue formation make it the material of choice for this procedure. In addition to MTA, various alternative biomaterials have been explored for apical barrier formation, including tricalcium phosphate, calcium hydroxide, freeze-dried bone, dentin derivatives, and bioceramic materials.[31-34] These materials aim to optimize apical healing while providing a reliable scaffold for mineralization and tissue regeneration.

Mineral Trioxide Aggregate (MTA) in Apical Barrier Technique

MTA is a hydrophilic biomaterial that forms a colloidal gel upon mixing with water.[35] Initially, MTA exhibits a pH of 10.2, which gradually rises to 12.5 during the setting phase and remains stable for up to three hours.[36,37] This highly alkaline environment contributes to MTA’s antibacterial properties, excellent biocompatibility, and capacity to stimulate hard tissue formation. [26]

In the apical barrier technique, thorough chemomechanical disinfection of the root canal system is performed before material placement. To enhance antimicrobial action, intracanal dressing with $Ca(OH)_2$ is applied for at least one week. At the following appointment, the $Ca(OH)_2$ dressing is removed, the canals are carefully dried, and a 3-4 mm thick MTA plug is compacted at the apical end of the canal. Once the MTA sets, the remaining root canal space is obturated using gutta-percha and a root canal sealer, ensuring a complete and biocompatible seal.

MTA has emerged as the material of choice in the apical barrier technique, offering several advantages over calcium hydroxide:[19]

- Superior Sealing Properties: MTA forms a highly effective apical seal, minimizing microleakage and reducing the risk of reinfection. Additionally, it exhibits the ability to set in a moist environment, ensuring a stable and predictable barrier even under challenging clinical conditions. [34,38]
- Biocompatibility and Safety: Research indicates that MTA does not induce adverse tissue reactions when extruded beyond the apex. Moreover, it has been shown to support periapical healing rather than compromising it, making it a safer alternative for apexification procedures.[38]

Limitations of MTA in Apical Barrier Technique

Despite its advantages, the apical barrier technique with MTA shares a fundamental limitation with traditional apexification—it does not support continued root development or improve the crown-to-root ratio.[38,39] As a result, teeth treated with this approach may remain structurally compromised, particularly in cases where root formation is incomplete.

Additionally, studies indicate that in teeth with short roots and thin dentinal walls, the risk of root fracture persists even after MTA treatment. However, this risk is believed to be lower compared to calcium hydroxide-treated teeth, where prolonged exposure may further weaken the dentin structure.[2]

Regenerative Endodontics

Regenerative endodontic treatment is based on three core principles of tissue engineering:

I. Identification of appropriate stem or progenitor cell sources,
II. Delivery of growth factors to guide cellular differentiation, and
III. Establishment of a 3D scaffold that supports sustained cellular proliferation and specialization.[40]

The apical papilla and periapical tissues of developing permanent teeth serve as key reservoirs for stem cells, offering a critical source for tissue regeneration.[41-43] Pulp revitalization is primarily dependent on the differentiation capacity of residual pulpal and periodontal stem cells.[44,45]

This process leads to the formation of a vascularized, connective tissue-rich living matrix, which gradually occupies the pulp space. Within this matrix, stem cells differentiate into odontoblast-like cells, initiating the deposition of hard tissue with characteristics that remain incompletely defined.[16] The outcome of this biological cascade represents a significant advancement in regenerative dentistry, offering the potential for functional root development and continued dentin formation, distinguishing it from traditional apexification approaches.

Revascularization in Regenerative Endodontics

Revascularization has emerged as a groundbreaking approach for managing necrotic, immature permanent teeth, offering a biologically driven alternative to traditional apexification. Traditionally, apexification was the treatment of choice for such cases, aiming to create an apical barrier to facilitate obturation. However, revascularization represents a superior approach, as it actively promotes continued root development rather than merely inducing apical closure.[16,46]

Unlike conventional techniques, revascularization stimulates apical healing while preserving the tooth's natural potential for growth. This biological process results in progressive apical narrowing, further root elongation, and dentinal wall thickening, ultimately leading to the formation of a natural, fully developed apex. [16,46] By fostering these structural improvements, revascularization significantly enhances long-term tooth prognosis, reinforcing its role as a preferred modality in regenerative endodontics.

Significance of Apical Foramen Width in Regenerative Endodontics

An essential factor influencing the success of regenerative endodontic treatment is the size of the apical foramen. Clinical evidence suggests that immature permanent teeth with an apical foramen diameter between 1.1 mm and 5 mm are the most ideal candidates for this approach.[47-50]

When the apical foramen is narrower, the restricted blood flow to the root tip may impede tissue regeneration and compromise clinical outcomes.[21,48] Adequate vascularization is crucial for the delivery of essential growth factors and the recruitment of stem/progenitor cells, both of which are fundamental to successful pulp-dentin regeneration. For optimal case selection and treatment planning, practical guidelines, contraindications, and key considerations for regenerative endodontics are summarized in Table 2.

Table 2: Key Considerations in Regenerative Endodontic Treatment Applications.

Considerations	Clinical Implications
Fully developed teeth generally have a better prognosis with conventional endodontic treatment	Before opting for regenerative endodontics, it should be evaluated whether an immature necrotic permanent tooth can be salvaged using apexification or non-surgical conventional root canal treatment
Inadequate root canal disinfection increases the risk of infection spreading to adjacent tissues	Proper chemo-mechanical preparation is essential to minimize this risk
Undiluted disinfectants should not be used (e.g., sodium hypochlorite)	Special care should be taken to prevent leakage and apical extrusion
Only necrotic or infected tissue inside the canal should be removed	Excessive instrumentation should be avoided to prevent weakening of thin dentinal walls and to minimize the risk of fracture
If apical bleeding does not fill the entire root canal space, revascularization may fail	Achieving adequate apical bleeding is a critical step in the regenerative process
Donor blood should not be introduced into the root canal, and unanchored exogenous stem cells should not be added due to significant health risks	The use of unproven or experimental techniques may compromise treatment success and patient safety
MTA should not be placed below the cemento-enamel junction (CEJ)	Positioning MTA too apically may prevent dentin regeneration at structurally weak fracture-prone areas
Minocycline should not be used for root canal disinfection to prevent tooth discoloration	Alternative antibiotics or antimicrobial agents should be considered
The cervical third of immature tooth roots, which is most prone to fracture, should be reinforced with composite and/or fiber posts	Restorative measures should be implemented to enhance long-term structural integrity

CONCLUSION

The management of necrotic and infected immature permanent teeth with open apices has undergone a significant transformation, shifting from traditional apexification techniques with calcium hydroxide or MTA to regenerative endodontic procedures. The driving force behind this paradigm shift is the ability of regenerative therapy to facilitate continued root development, offering a biological advantage over conventional methods. For cases where root length and dentinal thickness are insufficient, regenerative endodontic therapy is generally regarded as the preferred approach. However, patients should be fully informed about the possibility of unpredictable outcomes. In scenarios where regenerative treatment is not feasible, the MTA apical barrier technique serves as a viable alternative. Conversely, for cases with adequate root dimensions, both MTA apexification and traditional root canal treatment remain reliable options. A precise differential diagnosis is essential when determining the most appropriate intervention, especially among various treatment modalities, including apexogenesis, conventional root canal therapy, regenerative endodontics, vital pulp therapies (e.g., Cvek partial pulpotomy), and apexification. The clinical decision-making process for selecting the optimal treatment approach is outlined in Figure 1.[49]

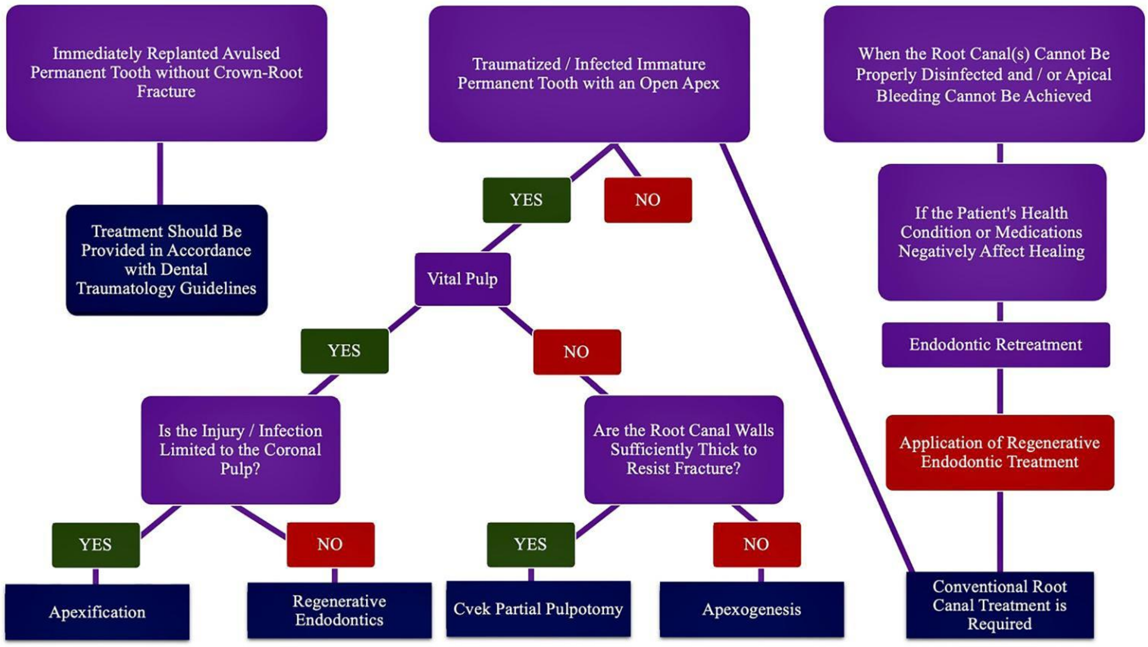

Figure 1: A flowchart assisting in the decision-making process for appropriate endodontic treatment options in immature permanent teeth.[49]

Despite the growing interest in regenerative endodontic procedures, the current lack of randomized clinical trials and long-term clinical data presents a challenge in defining standardized case selection criteria. Therefore, further well-designed clinical studies are necessary to establish evidence-based guidelines for the predictable and effective application of regenerative endodontic therapy.

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Comparison of Accuracy Between Traditional and Various Digital Implant Measurements for Implant-Supported Complete Arch Prostheses

İmplant Destekli Tam Ark protezler İçin Geleneksel Ve Çeşitli Dijital İmplant Ölçüleri Arasındaki Doğruluğun Karşılaştırılması

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ABSTRACT

When a fixed prosthetic restoration is desired to be made on multi-unit implants for patients with complete edentulism; the accuracy of the impression process is very important for the passive compatibility of the prosthesis, its aesthetic, its ability to completely fulfill its function and to maintain its structural integrity during applicatıon.Today, the measurements required for the production of full arch fixed prostheses superstructures of multi-unit implants applied for total edentulism rehabilitatıon can be obtained by traditional and digital methods. While traditional impression-taking methods are time-consuming, invasive, lead to complications and impression errors, intraoral scanners shorten treatment times and increase patient comfort with fast digital scanning.The easy storage and transmission of the digital data enables more effective communication between dentists, laboratories and other healthcare professionals. However, intraoral scanners have their advantages but also some uncertainties.

In this review, models obtained with the traditional method and intraoral scanner used in the rehabilitation of multi-unit implant-supported full arch fixed prosthesis with complete edentulism are compared and their contributions to prosthetic success are presented.

Keywords: *Full arch implant impressions, conventional implant impressions, digital implant impressions*

ÖZ

Tam dişsizliğe sahip hastalara multi-ünit abutmentlar üzerine sabit protetik restorasyon yapılmak istenildiğinde; protezin pasif uyumluluğu, estetiği, işlevini tam olarak yerine getirebilmesi ve işlev sırasında yapısal bütünlüğünü korumasında ölçü işleminin doğruluğu oldukça önemlidir. Günümüzde multi-ünit abutmentlardan oluşan tam ark sabit protezlerin üst yapılarının üretilmesinde geleneksel ve dijital ölçü alma yöntemleri kullanılmaktadır. Geleneksel ölçü alım yöntemleri uzun süre alması, invaziv olması, komplikasyonlara ve ölçü hatalarına yol açması nedeniyle en başa dönülmesine neden olurken; ağız içi tarayıcılar hızlı dijital tarama yaparak tedavi sürelerini kısaltır ve hasta konforunu artırır. Elde edilen dijital verilerin kolayca depolanması ve iletilmesi, diş hekimlerinin laboratuvarlar ve diğer sağlık profesyonelleriyle daha etkili iletişimini sağlar. Fakat ağız içi tarayıcılar avantajlarıyla beraber bazı belirsizlikleri de beraberinde getirmektedir.

Bu derlemede tam dişsizliğe sahip multi-ünit abutment üstü tam ark sabit protez rehabilitasyonunda kullanılan geleneksel yöntem ve ağız içi tarayıcıyla elde edilen modeller karşılaştırılarak protez başarısındaki katkıları sunulmuştur..

Anahtar Kelimeler: *Tam ark implant ölçüleri, konvansiyonel implant ölçüleri, dijital implant ölçüleri*

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INTRODUCTION

Implant-supported fixed prostheses have become a routine procedure for the replacement of missing teeth to fulfill functional, biological, and aesthetic requirements.[1] A dental impression is a negative replica used to create a positive reproduction of the oral structures, serving either as a permanent record or utilized in the fabrication of a dental prosthesis.[2] Accurate indexing of implant positions from the patient's mouth to the dental laboratory is essential to minimize prosthetic misfit. Therefore, it is crucial to fabricate a prosthesis compatible with intraoral tissues based on a precise and accurate impression.[3] In implant-supported fixed full-arch prostheses fabricated as a single unit on multiple implants, precise impressions are unquestionably essential for the accuracy of the implant suprastructure and for achieving long-term clinical success.[4]

Traditional and digital implant impression techniques transfer the intraoral positions of dental implants to the working cast. Accurate transfer of each implant's position relative to adjacent implants or teeth is critical for the design and adaptation of implant-supported prostheses, thus ensuring long-term success of implant treatment by preventing mechanical and biological complications. Despite advancements in impression techniques and materials, outcomes in routine clinical practice frequently remain unsatisfactory, highlighting the ongoing need for further improvements.[5]

In conventional methods, implant analogs, impression copings, and impression materials are utilized. Any displacement of implant components during removal of the impression tray from the mouth and throughout laboratory procedures negatively affects the accuracy of the prosthesis.[6] Negative factors affecting impression accuracy can influence prosthetic components, potentially resulting in complications such as screw loosening, veneer fractures, and framework fractures.[7]

Digital systems utilizing optical scanners to capture implant positions and visualize them on virtual models represent a novel approach for impression-taking in implant-supported prostheses, and they are anticipated to gradually replace conventional impression techniques.[8] In digital systems, data acquisition is performed through direct and indirect approaches. In the indirect method, images are digitized by scanning conventional impressions or the resulting stone casts using laboratory scanners, whereas in the direct method, images obtained via intraoral scanners are utilized.[9] Compared to conventional methods, sufficient evidence regarding the accuracy of digitally fabricated working casts is still lacking. Furthermore, while the digital impression technique has been validated for single-unit restorations, its accuracy for full-arch prostheses remains controversial.[10,11]

Impression Techniques for Implant-Supported Prostheses

1. Conventional Impression Methods

Traditionally, three different techniques are employed for implant impressions:

1.1. Indirect Impression Technique (Transfer Technique/Closed Tray)

1.2. Direct Impression Technique (Pick-up Technique/Open Tray)

1.3. Snap-on (Press-fit) Impression Technique. [4]

While many authors report greater accuracy with the closed tray impression technique[12] others advocate splinting of impression copings[13] or the open tray technique without splinting.[14] Some studies have reported no difference between the open-tray and closed-tray impression techniques[15], nor between splinted and non-splinted techniques.[16] However, in a study evaluating implant impression accuracy, splinting of impression copings for internal connection implants resulted in higher accuracy, concluding that splinted impressions produced more accurate models than non-splinted impressions, especially when the number of implants was four or greater.[4]

Currently, elastomeric impression materials are commonly preferred in the fabrication of implant-supported prostheses.[17] Due to their high accuracy and dimensional stability, polyether (PE) and vinyl polysiloxane (PVS) impression materials are widely favored.[18] In conventional impression techniques applied to internally connected implants, the use of high-rigidity impression materials, such as polyethers, appears advantageous for achieving more accurate outcomes.Owing to their excellent properties, including high rigidity, polyethers are frequently utilized in implant prosthetics compared to polyvinyl siloxanes. With their superior hydrophilicity, polyethers reliably capture intraoral details and may serve as an alternative to other impression materials in partially or fully edentulous patients, particularly when saliva or blood is present.[6]

2. Digital Impression Techniques

Digital systems are classified into direct and indirect methods based on data acquisition techniques. The direct method utilizes images obtained through intraoral scanners, whereas the indirect method employs images derived from impressions or casts scanned using laboratory scanners.[9]

2.1 Direct Method:

Intraoral scanners (IOS) are medical devices based on three-dimensional (3D) measurement systems capable of capturing the shape and dimensions of dental arches and reconstructing 3D models of teeth and soft tissues within the oral cavity, thereby enabling complete digitalization of intraoral anatomy.[19,20] The most commonly utilized operating principles for intraoral scanning systems include Triangulation, Confocal (Parallel Confocal), and Active Wavefront Sampling.[21]

2.1.1. Triangulation: This imaging method is based on the principle that the position of one point of an object can be calculated when the positions and angles of two other points are known. The two reference points of the triangle can be identified either by a single detector using a prism to obtain images from two different angles or by utilizing two separate detectors.[21] An example of this technology is the CEREC Bluecam (Sirona Dental System GmbH).[9] Generally, CEREC provides acceptable results.[22,23] However, its accuracy is comparable to that of conventional impression techniques. An in vitro study by Ender & Mehl concluded that the accuracy of digital impressions made with Cerec AC and Lava COS systems was similar to conventional method.[24] When using CEREC AC, the scanned surfaces must be treated with an anti-reflective matting agent to prevent reflections.[25]

2.1.2. Confocal: This imaging technique is based on acquiring focused and unfocused images at selected depths. Determination of the image's focal field depends on the lens's focal length and its distance to the object. A dental image can be reconstructed through successive images taken from different angles at varying focal points and depths. However, image clarity in this method may be affected by the clinician's hand movements.[21] The iTero scanner (Invisalign; Cadent Inc., Or-Yehuda, Israel) employs parallel confocal imaging technology to capture digital images and transform them into three-dimensional images (Andriessen, Rijkens, Van Der Meer, & Wismeijer, 2014). Similarly, the 3Shape TRIOS 3 scanner (Copenhagen, Denmark) utilizes parallel confocal microscopy, in which emitted light beams parallel to the scanned surface reflect back along the same optical pathway, producing images at different depths proportional to the distance from the focus to the object.[26] Both the iTero[25] scanner and TRIOS 3 do not require special surface preparations (powder, spray, etc.) of the teeth being scanned. Recent studies have indicated that TRIOS 3 is among the most accurate intraoral scanners when compared to other systems.[27]

2.1.3. AWS (Active Wavefront Sampling): This imaging method utilizes a camera equipped with an off-axis aperture capable of continuous oscillation. The optical module follows a circular path around the optical axis, capturing sharp images to determine surface topography. Distance and depth data are calculated for each point, thus creating the model.[21] An example of this method is the Lava Chairside Oral Scanner (Lava C.O.S., 3M ESPE, St. Paul, MN). Lava C.O.S. is a 3D video system capturing real-time images at 20 three-dimensional frames per second. Following the scanning procedure, a post-processing cycle is necessary to recompute the recorded data and correct potential errors, resulting in a high-resolution digital model uploaded to 3M.[25]

2.2. Indirect Method:

Laboratory scanners can also be referred to as extraoral scanners, model scanners, impression scanners, and desktop scanners.[29] Laboratory scanners are utilized to convert conventionally produced plaster casts into digital files.[30] Consequently, indirect extraoral digitization procedures can inherently include errors related to conventional methods, such as impression-taking, model fabrication, and impression distortion.[31] Some researchers have reported that direct scans obtained using intraoral scanning devices result in accuracy equivalent to or even superior to models digitized indirectly via extraoral scanning of plaster casts.[29]

Digital impression constitutes the first step of a fully digital protocol, and its accuracy depends on multiple factors including the optical system of the intraoral scanner, image processing software, algorithms used for aligning, merging, and resolving triangulation networks, readability of scan bodies, compatibility with virtual design libraries, scanning pathway, patient-related factors (e.g., salivary flow rate, tongue size and position, mouth opening), as well as operator experience.[25,32]

Advantages of Digital Impression Systems

Digital impression scanners eliminate the need for conventional impression trays, the intraoral placement of impression materials, disinfection, and shipment of impressions to the laboratory.[20] Other claimed advantages include improved accuracy[33] by minimizing operator-dependent variability and eliminating material-related dimensional changes (e.g., impression and cast materials), as well as enhanced patient comfort.[34]

Digital impressions obtained with intraoral scanners have demonstrated satisfactory outcomes for single crowns and short-span bridges fabricated on both natural teeth[35] and dental implants.[36]

Disadvantages of Digital Impression Systems

The limited adoption of intraoral scanners among dental professionals can be attributed to several factors, including their high cost, complexity of equipment, the requirement for training and practical experience for proper use, limitations similar to conventional methods in capturing subgingival areas, sensitivity to the oral environment (presence of moisture, saliva, or blood), comparable accuracy results obtained in comparative studies between conventional and digital impression techniques, and high susceptibility to operator and patient movements.[37]

Summary of Studies on Digital Impression Accuracy and Precision:

Marques et al.[38] , in their study comparing the accuracy and precision of dental arches during single-implant digitization using partial or full-arch scans, utilized a partially edentulous maxillary model with one implant (4.0 × 11 mm; Proactive Straight Implant, Neoss, Woodland Hills, CA, USA) and an intraoral scan body (Intra-Oral Scanbody, Neoss, Woodland Hills, CA, USA) positioned in the region of the left central incisor. Partial arch scans from the distal of the left second molar to the distal of the right canine were performed using an IOS with 6.9 µm precision (TRIOS 3 v 1.4.7.5; 3Shape, Copenhagen, Denmark). The accuracy of intraoral scans was significantly influenced by whether scans were partial or full-arch. Partial arch scans demonstrated higher accuracy than full-arch scans, though their precision was found to be similar. Considering accuracy across different regions of the arch, anterior regions exhibited greater accuracy compared to posterior regions for both partial and full-arch scans.

Vandeweghe et al.[11] and Imburgia et al.[39] compared several intraoral scanners and concluded that accuracy levels varied among different devices, indicating that not all intraoral scanners are sufficiently accurate for full-arch implant impressions.

While intraoral scanner (IOS) systems can provide predictable and accurate digital scans for partially edentulous patients, certain difficulties have been reported, including operator experience, file size limitations, and the absence of reliable hard tissue references under edentulous conditions. Currently available IOS systems cannot yet reliably scan completely edentulous jaws due to the lack of distinct anatomical reference structures, complicating the software's ability to integrate individual images accurately.[40] According to Lee et al.[41], digital implant impression accuracy was influenced by implant angulation regardless of IOS type, achieving highest accuracy when the distal terminal implant was inclined mesially. In contrast, Menini et al.[6] reported that angulation of tilted posterior implants did not affect the accuracy of the digital technique. Due to such factors, transforming scan bodies into implant analogs using a digital library may result in linear and angular displacement errors; therefore, the conventional open-tray impression technique is recommended at the implant level for full-arch, single-unit implant-supported prostheses.[42]

Rutkūnas et al.[40] , in their study evaluating digital scanning accuracy of partially and fully edentulous jaws using five different intraoral scanners (IOS) with and without additional artificial reference points, fixed polymerized glass ionomer cement (Fuji Plus; GC) reference objects using adhesive (Super Moment Glue; Henkel) at specific locations: one centrally positioned in the edentulous area, six distributed among the scan bodies, and three on the palate of a partially edentulous model. Subsequently, five IOS systems—Primescan v5.0.1 (Dentsply Sirona), TRIOS 3 v1.18.2.10 (3Shape A/S), TRIOS 4 v19.2.2 (3Shape A/S), CARESTREAM 3600 v3.1.0 (Carestream Dental), and Medit i500 v2.0.3 (Medit)—were utilized for digital scanning. Their findings revealed that, except for vertical displacement accuracy observed with Medit i500 and CARESTREAM 3600, additional artificial reference points did not significantly influence accuracy parameters in partially edentulous scans. However, when employing different IOS devices, fully edentulous regions showed variable accuracy and precision: Medit i500 displayed variation for distance, PRIMESCAN and TRIOS 4 for angle measurements, and all systems except TRIOS 4 exhibited variations for vertical displacement precision. Ultimately, the study concluded that additional artificial reference points have limited effects on scanning accuracy parameters for partially edentulous cases, whereas their use significantly improves scanning accuracy in fully edentulous arches.

In an in vitro study by Kim et al.[42] , to compare the accuracy and precision of linear and angular displacement of implant analogs, an epoxy resin master cast was fabricated by replicating an edentulous maxillary gypsum model containing six implant analogs positioned at the right first molar, right first premolar, right lateral incisor, left lateral incisor, left first premolar, and left first molar regions. While the conventional method employed a splinted open-tray impression technique using medium-viscosity polyvinyl siloxane impression material (Aquasil Monophase; Dentsply Sirona), the digital method involved intraoral scanning utilizing the TRIOS 3 scanner (3Shape) combined with scan bodies (TruScan body; TruAbutment). The study reported that intraoral digital scanning resulted in lower accuracy compared to the conventional splinted open-tray impression technique. The conventional open-tray impression technique demonstrated greater precision across all implant analog positions compared to intraoral digital scanning. Additionally, conventional open-tray impressions produced significantly smaller angular deviations than intraoral digital scans; however, this difference was not considered clinically significant.

In an in vitro study conducted by Menini et al.[6] evaluating the accuracy of various impression techniques on multi-unit abutments, eight impression techniques were tested on a master cast simulating a four-implant jaw designed for full-arch rehabilitation, in which four low-profile implant analogs were embedded into a gypsum cast at canine (positions 13 and 23) and first molar (positions 16 and 26) locations. Seven conventional impression methods were selected, including the open-tray technique with polyether [Impregum Penta, 3M ESPE, Saint Paul, MN, USA]; open-tray polyether technique with impression copings splinted by acrylic resin; closed-tray technique with polyether; open-tray technique with polyether [Ramitec Penta, 3M ESPE]; open-tray polyether technique with acrylic resin-splinted impression copings; closed-tray polyether technique; and open-tray technique with plaster impression material [BF Plaster, Dental Torino, Torino, Italy]. Additionally, five digital impressions (DIs) of the master cast were taken using a True Definition Scanner [3M ESPE]. Prior to scanning, four polyetheretherketone (PEEK) scan bodies were screwed into the implant analogs on the master cast to digitally capture implant positions. Subsequently, a homogenous layer of matting powder [3M High-Resolution Scanning Spray, 3M ESPE] was applied to the master cast for digitization procedures. The intraoral scanning procedure commenced at implant position 26 and proceeded in a continuous mode around all scan bodies. After reaching implant position 16 to complete an initial general scan, an additional circular scanning pattern was performed around each scan body. The study concluded that intraoral scanners could serve as an alternative to conventional impression techniques for fabricating full-arch implant-supported prostheses with satisfactory passive fit; however, it was noted that digital impressions showed reduced angular deviations when the inter-implant distances were shorter.

Ciocca et al.[32], in their in vitro study evaluating the accuracy of digital scanning using a single intraoral scanning system, placed six implants in a completely edentulous arch. They reported that the error values associated with scan bodies progressively increased with the distance between them. Particularly, the increased inter-implant distance in the most posterior regions of the edentulous arch significantly contributed to higher error values.

Papaspyridakos DDS et al.[43] compared the three-dimensional deviations between full-arch digital scans and conventional implant impressions in edentulous maxillae and mandibles. In their study, a total of 204 implants were placed across patients, ranging from four to six implants per arch, using a prosthetically driven surgical approach. For digital impressions planned at the multi-unit abutment level, SRA scan bodies for the Straumann system and Elos and Neodent scan bodies for the Nobel Biocare system (due to their interchangeability) were employed using a TRIOS 3 (3Shape A/S, Copenhagen, Denmark) intraoral scanner. For conventional impressions, a splinted open-tray technique at the abutment level using polyether impression material was implemented. The results indicated three-dimensional deviations between full-arch digital scans and conventional models as 85 ±25 µm for the maxillary group and 92 ±23 µm for the mandibular group.In another in vivo study by Chochlidakis et al.[44], comparing digital and conventional implant impressions in 16 patients with edentulous maxillae, the mean three-dimensional deviation (mean ± SD) between virtual models obtained from intraoral full-arch maxillary digital scans and digitized models from conventional implant impressions was found to be 162 ±77 µm. These findings were within the clinically acceptable threshold and consistent with previously reported values.[43]

In an in vitro study conducted by Kosago et al.[11] , the three-dimensional deviation accuracy of conventional and various intraoral scanner impression methods was compared to stereophotogrammetry (PIC - Precise Implant Capture) for a fully edentulous mandibular arch containing five implants (three straight and two 17° angled screw-retained abutments). The conventional method utilized the splinted open-tray technique with polyether impression material, whereas digital methods involved intraoral scanners TS (Trios 4), IT (iTero Element 2), and PS (Primescan). Results indicated that PIC exhibited the lowest three-dimensional deviation, achieving the highest accuracy (48.74 ± 1.80 µm) and precision (5.46 ± 1.10 µm), followed respectively by Trios 4, Primescan, iTero Element 2, and the conventional method. The conventional method demonstrated the highest three-dimensional deviation in terms of accuracy (141 ± 5.58 µm) and precision, significantly differing from the others. Among different intraoral scanners, Trios 4 and Primescan provided greater accuracy compared to iTero Element 2. Consequently, the study concluded that conventional methods utilizing splinted open-tray impression techniques were less accurate than digital impressions and stereophotogrammetry techniques.

In a clinical study by Chochlidakis et al.[44] comparing the accuracy of digital and conventional maxillary implant impressions in completely edentulous patients, a total of 16 patients underwent implant treatment. Four patients received maxillary fixed complete dentures (FCD) supported by 4 implants, five patients received FCDs supported by 5 implants, and seven patients received FCDs supported by 6 implants. In the conventional method, an open-tray impression technique at the abutment level using high and low viscosity vinyl polysiloxane (VPS) impression materials (3M Imprint, 3M, St. Paul, MN) was employed, whereas a True Definition intraoral digital scanner was used for the digital method. In this study, the average three-dimensional deviation between full-arch models generated by conventional and digital techniques was found to be 162 µm. This deviation is within the previously reported clinically acceptable threshold (up to 200 µm). It was also observed that three-dimensional deviations increased with a greater number of implants in the arch; however, this increase was not clinically significant.

CONCLUSION

Digital models obtained through intraoral scanners have shown promising results compared to conventional methods. However, in completely edentulous cases, implant positioning may not yield consistent results for each operator due to inherent variations in scanning characteristics and the physical dimensions of intraoral scanners. This situation underscores the necessity of specialized operator training for digital techniques. Fixation of the scan body to a cast model typically results in fewer positioning errors compared to in vivo procedures, as in vitro studies lack factors such as mucosal mobility, saliva, and tongue movements that influence the precision of in vivo measurements.[32] Nevertheless, further clinical studies are require.

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The Influence of Oral Microbiome on Oral Cancer Etiology

Oral Mikrobiyomun Oral Kanser Etiyolojisindeki Etkisi

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ABSTRACT

Research on the etiology of cancer suggests that bacteria playing a role in inflammatory processes, in addition to factors such as genetic factors, tobacco and alcohol use, environmental factors, aging, nutrition, and family history, can contribute to the development of cancer in the oral cavity and body. Research evaluating the relationship between inflammation and cancer demonstrates that cancer is not only a cellular-level process but also a complex one involving interactions with the organism's immune system. Studies investigating the relationship between oral cancer and the microbiome emphasize the significant impact of identifying the disease's pathogenic mechanisms on early diagnosis and determining effective treatment strategies. It has been shown that periodontal disease, in particular, may be influential in the development of oral cancer, various bacteria may play a role in cancer development, and changes in the oral microbiome may affect cancer prognosis. Research on the potential roles of bacteria such as C. albicans, Porphyromonas gingivalis, Fusobacterium nucleatum, Treponema denticola, and Streptococcus spp. in the development of oral cancer may facilitate the development of new approaches in cancer treatment. In this context, further research into the effects of the oral microbiome on cancer development and prognosis is crucial.

Keywords: *Oral cancer, microorganism, etiology, periodontal disease*

ÖZ

Kanser etiyolojisi üzerine yapılan araştırmalar, genetik faktörler, tütün ve alkol kullanımı, çevresel faktörler, yaşlanma, beslenme, aile öyküsü gibi faktörlerin dışında enflamatuvar süreçlerde rol oynayan bakterilerin de oral kavitede ve vücutta kanser gelişimine katkıda bulunabileceğini ortaya koymaktadır. Enflamasyon ve kanser ilişkisinin değerlendirildiği araştırmalar, kanserin sadece hücresel düzeyde değil, aynı zamanda organizmanın bağışıklık sistemiyle olan etkileşimlerini de içeren kompleks bir süreç olduğunu göstermektedir. Oral kanser ile mikrobiyom arasındaki ilişkiye yönelik araştırmalarda hastalığın patojenik mekanizmalarının belirlenmesinin erken teşhiste ve etkili tedavi stratejilerini belirlemede önemli bir etkiye sahip olduğunu vurgulamaktadır. Özellikle periodontal hastalığın oral kanser gelişiminde etkili olabileceği, çeşitli bakterilerin kanser gelişiminde rol oynayabileceği ve oral mikrobiyomdaki değişikliklerin kanser prognozunu etkileyebileceği gösterilmiştir. C. albicans, Porphyromonas gingivalis, Fusobacterium nucleatum, Treponema denticola ve Streptococcus spp. gibi bakterilerin oral kanser gelişimindeki potansiyel rolleri üzerine yapılan araştırmalar, kanserle mücadelede yeni yaklaşımların geliştirilmesine olanak sağlayabilir. Bu bağlamda, oral mikrobiyomun kanser gelişimi ve prognozu üzerindeki etkilerinin daha detaylı şekilde araştırılması önem arz etmektedir.

Anahtar Kelimeler: *Oral kanser, mikroorganizma, etiyoloji, periodontal hastalık*

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INTRODUCTION

Cancer is defined as the disruption of mechanisms that regulate cell proliferation, leading to the uncontrolled growth of atypical cells that replace healthy tissues and ultimately render the organism dysfunctional. In healthy cells, growth is tightly regulated by mechanisms that initiate and halt proliferation, and upon completing their normal lifespan, cells are eliminated via a process known as "apoptosis," or programmed cell death. (Figure 1) Apoptosis is a crucial mechanism that plays a critical role in cell renewal, immune system development, embryonic growth, and chemical-induced cell death, as well as in maintaining homeostasis in adult tissues.[1-3] Disruptions in this mechanism have been shown to contribute to various developmental, inflammatory, degenerative, and neoplastic diseases. Research on cancer development in relation to apoptosis underscores the complexity of cellular control mechanisms.[1,4,5] Specifically, factors such as chronic inflammation, increased cellular stress, and the accumulation of DNA damage can disrupt normal cellular balance, creating conditions that favor the proliferation of atypical cells. Thus, the multifactorial nature of cancer emerges from the convergence of various contributing factors. Additionally, investigations into the relationship between inflammation and cancer indicate that cancer is not merely a cellular phenomenon but also involves complex interactions with the immune system of the organism.

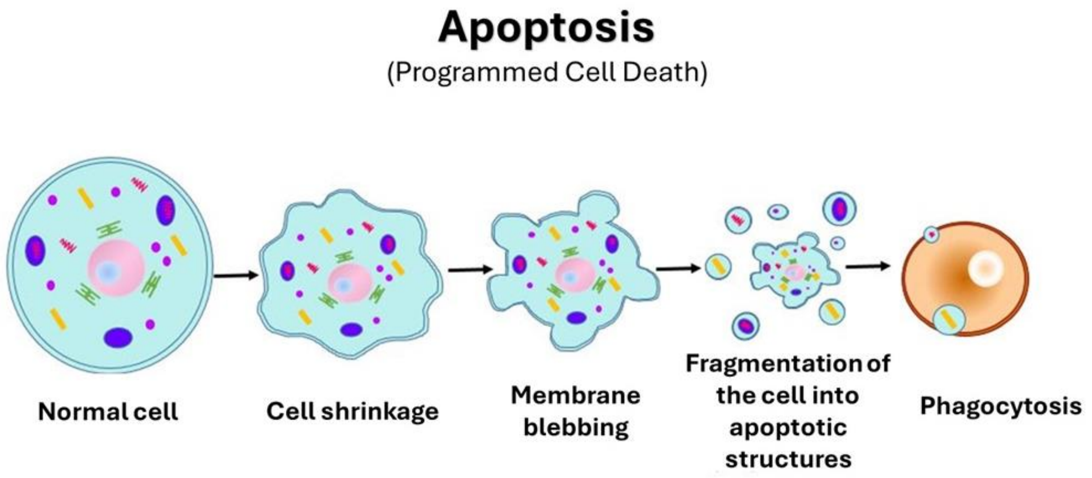

Figure 1: After completing its normal lifespan, the cell undergoes apoptosis and is then phagocytosed.[5]

Oral Microbiome and Cancer

Research on cancer etiology suggests that, in addition to well-known causes, approximately 15-20% of all cancers are associated with chronic inflammation.[6] Literature reports indicate that chronic inflammation induces both local and systemic immunosuppression.[7] In the development of oral cancer, carcinogenic alterations and inflammatory triggers act through an interrelated intrinsic and extrinsic pathway contributing to carcinogenesis. (Figure 2)

Intrinsic factors include genetic and epigenetic events, which, through oncogene activation or tumor suppressor inactivation, induce malignant transformation in keratinocytes and promote the production of inflammatory cell mediators associated with cancer. Active cytokines and chemokines produced during chronic inflammation, along with prostaglandins, reactive oxygen species, and various transcription factors, directly or indirectly affect eukaryotic cell cycles and signaling pathways, inhibiting apoptosis and promoting cell proliferation. Extracellular pathway is associated with an underlying inflammatory /infectious condition, activating transcription factors responsible for tumor development through produced inflammatory cytokines, thus supporting carcinogenesis. Both mechanisms lead to the production of transcription factors that sustain inflammation and cancer, ultimately fostering a microenvironment in which inflammation and cancer mutually reinforce each other.[8-10] Consequently, chronic inflammatory disorders such as oral lichen planus, oral submucous fibrosis, and oral discoid lupus erythematosus are recognized as conditions predisposing to the development of oral squamous cell carcinoma (OSCC), which is the most common malignancy of the oral cavity.[9]

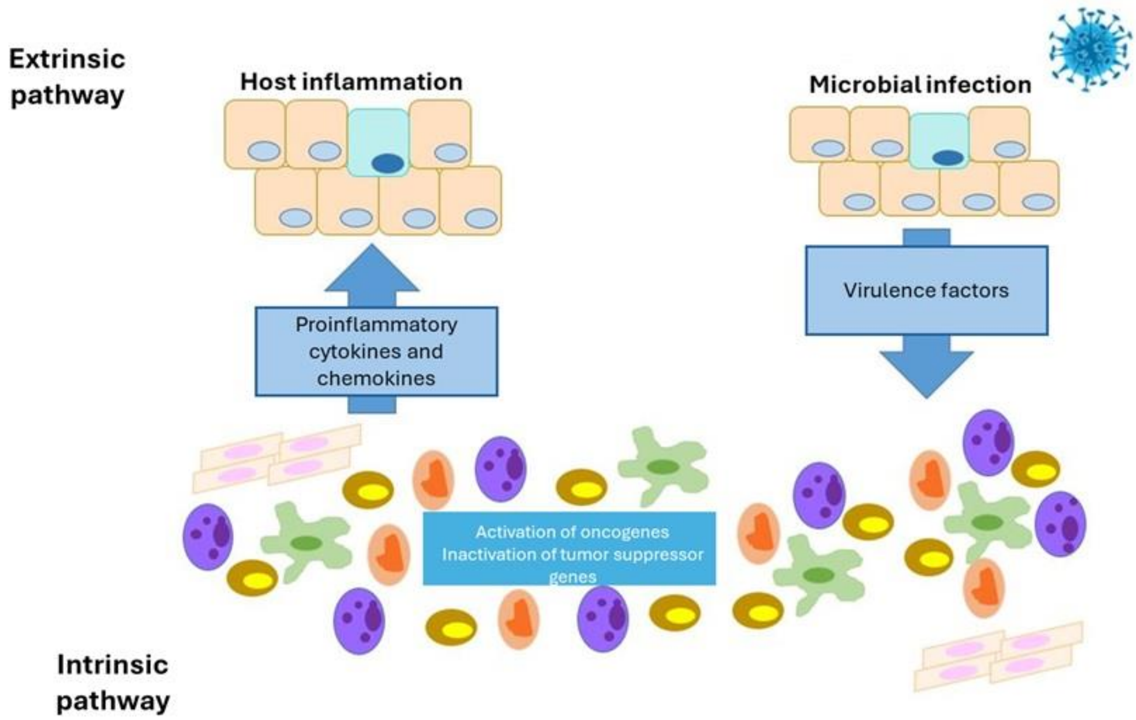

Figure 2: Both the intrinsic pathway, composed of genetic and epigenetic factors, and the extrinsic pathway, which triggers the production of inflammatory cytokines, play a role in initiating carcinogenic changes in the oral mucosa. As a result of both pathways producing inflammatory mediators and transcription factors that induce cancer formation, a microenvironment is created where inflammation and cancer feed and promote each other.[8]

The primary etiological factors contributing to cancer development are genetic predisposition, tobacco and alcohol consumption, environmental factors, aging, diet, lifestyle, stress, family history, and infections.[7] In addition to the mediators produced during local inflammatory processes in the oral cavity, bacterial components that induce inflammation are also thought to contribute to cancer development at the systemic level.[6,7,11-14] (Figure 2) The International Agency for Research on Cancer (IARC) currently classifies 11 microorganisms as "carcinogenic" to humans. These microorganisms include *Helicobacter pylori*, Hepatitis B and C viruses, *Opisthorchis viverrini*, *Clonorchis sinensis*, Human papillomavirus, Epstein-Barr virus, Human herpesvirus 8 (HHV-8), Human T-cell Lymphotropic Virus 1 (HTLV-1), *Schistosoma haematobium*, and Human Immunodeficiency Virus-1 (HIV-1).[7,15] *Helicobacter pylori*, which has the most well-established association with cancer development in humans, is classified as a class I carcinogen.[10,15,16] Since *Helicobacter pyl*ori was recognized as an agent causing gastric cancer,[17-19] significant evidence has emerged suggesting that oral bacteria also play a role in cancer development within the body.[7,13] It has been demonstrated that microorganisms not only initiate chronic inflammation but also contribute to cancer development by triggering the production of carcinogens such as N-nitroso compounds and acetaldehyde.[10,15,20,21] Acetaldehyde, a highly potent genotoxic metabolite, is a metabolic byproduct of ethanol and is produced through the oxidation of ethanol by the oral microbiota.[15,22] It has been determined that the produced acetaldehyde causes DNA damage in oral epithelial cells.[23] The increased production of acetaldehyde in the oral microbiota of chronic smokers suggests that, alongside key risk factors such as alcohol and tobacco use, the oral microbiome should also be considered a synergistic risk factor or cofactor.[15,21]

Research on the relationship between oral cancer and the microbiome emphasizes that identifying the pathogenic mechanisms of the disease has a significant impact on early diagnosis and the development of effective treatment strategies.[18] Given that structural changes in the oral microbial ecosystem support chronic inflammatory processes in the oral cavity and facilitate tumor progression,[18,24] poor oral hygiene and periodontal disease have been reported to alter bacterial ecology and may be associated with oral cancer independently of other risk factors.[16,25-28]

Periodontitis is defined as a chronic inflammatory disease caused by specific bacteria, and the bacteria responsible for this condition can persist by resisting immune responses, particularly when the disease remains untreated.[29,30] Inflammation caused by periodontitis not only leads to severe damage both locally and systemically, but also contributes to malignant tissue transformation by enhancing the synthesis of carcinogenic compounds, by inhibiting cellular apoptosis, or both.[25,28,31-33] Various studies have demonstrated that periodontal pathogens, primarily *Porphyromonas gingivalis, Fusobacterium nucleatum*, and *Treponema denticola*, as well as other pathogens such as *Streptococcus sp., Peptostreptococcus sp., Prevotella sp., Capnocytophaga gingivalis, Veillonella, Actinomyces, Clostridium, Haemophilus*, and members of the *Enterobacteriaceae* family, are positively associated with lesions carrying a risk of oral cancer (oral potentially malignant disorders—OPMD) and oral cancers.[17-19,28,29,32,34-38]

Porphyromonas gingivalis, Porphyromonas catoniae, and *Fusobacterium nucleatum* have the capacity to enhance immune receptors and disrupt tight junctions between cells. Therefore, they are believed to be responsible for the oral epithelial changes occurring during the carcinogenesis process.[15,39] It has been found that *Fusobacterium, Peptostreptococcus, Neisseria*, and *Parvimonas* populations have increased in samples taken from OSCC cases compared to healthy controls, and these microorganisms have been more prevalent in advanced-stage cancer cases than in early-stage disease.[16] A study in which microbiome samples were collected and analyzed using the oral rinse method after surgery has demonstrated that the re-emergence of commensal bacteria such as *Streptococcus* and *Rothia*, along with the reduction of periodontopathogens such as *Capnocytophaga, Prevotella 7*, and *Leptotrichia*, contributed to increased survival rates six months after surgery.[40]

The literature includes numerous studies on different microbial families that may be associated with the development and prognosis of OSCC lesions. The most frequently highlighted pathogenic microorganisms and their mechanisms of action are presented below.

Porphyromonas gingivalis

P. gingivalis is an anaerobic gram-negative bacterium which is one of the most significant pathogens implicated in the development of chronic periodontitis. In addition to periodontitis, *P. gingivalis* has been associated with various oral and systemic diseases, including Alzheimer's disease, gastrointestinal cancers, and oral cancer.[17] Numerous studies have elucidated the mechanisms through which it promotes cancer development.[3,14] It has been reported that *P. gingivalis* inhibits programmed cell death in primary gingival epithelial cells, accelerates gingival epithelial cell proliferation, promotes the metastatic spread and invasion of OSCC cells, and induces chronic inflammation—a potential pathway contributing to carcinogenesis.[41] In a study conducted by Liu et al. (2020), *P. gingivalis* was found to inhibit the phagocytosis of OSCC cells by macrophages, enhance the expression of genes encoding pro-tumor molecules in OSCC cells, and accelerate the formation of an immunosuppressive tumor microenvironment. As a result of these effects, a novel mechanism through which *P. gingivalis* promotes OSCC progression has been revealed.[41] The ability of bacteria to enhance the "irregular and unlimited proliferation capacity"—which is a hallmark of tumor cells—is considered a pro-tumorigenic effect that supports tumor formation. This characteristic is prominently exhibited in the cells of tissues infected by *P. gingivalis*.[3,19] It has been demonstrated that *P. gingivalis* positivity is higher in patients with TNM (tumor, lymph node, and metastasis) stage III-IV disease, poor differentiation, and lymph node metastasis.[3] Studies have indicated that apoptosis is inhibited in infected epithelial cells, resulting in the development of an anti-apoptotic phenotype associated with cancer.[42] Proteomic studies demonstrate that infection of gingival epithelial cells with *P. gingivalis* leads to alterations in specific protein concentrations and phosphorylation levels. These bacteria primarily affect pathways associated with cyclins, cyclin-dependent kinases, and the p53 protein, consequently, disrupting the regulation of the cell cycle.[42,43] Therefore, infection caused by *P. gingivalis* is considered a potential risk factor for oral cancer.

Fusobacterium nucleatum

F. nucleatum is a gram-negative, obligate anaerobic bacterium found in the oral cavity, urinary tract, intestines, and upper digestive tract of both healthy and diseased individuals.[44] However, the frequent detection of *F. nucleatum* in various oral and systemic infections including periodontitis, angina, lung abscess, chronic otitis, sinusitis, peritonsillar, cerebral, and gynecological abscesses, inflammatory bowel disease, ulcerative colitis, Crohn's disease, neonatal sepsis, Lemierre's syndrome, and infective endocarditis, has led to its identification as a potent opportunistic pathogen.[44] As one of the most common species causing periodontitis and extraoral infections, *Fusobacterium nucleatum* has been detected at higher levels in the tissue and saliva samples of head and neck squamous cell carcinoma patients compared to healthy controls. Consequently, it has been suggested that this bacterium may play a role in the development of gastrointestinal and oral cancers.[15,17,28,38] Its presumed carcinogenic potential has been attributed to its pro-inflammatory effect, which occurs primarily through the induction of various cytokines, including TNF-α, IL-6, IL-8, IL-10, and IL-12.[44,45] Additionally, *Fusobacterium nucleatum* facilitates the formation of biofilms by enabling the aggregation of various species, acting as a crucial "bridge" between early and late colonizers. The frequent co-detection of *F. nucleatum* and *P. gingivalis* in oral biofilms suggests that *F. nucleatum* colonizes the environment before *P. Gingivalis*, and is essential for its establishment. Consequently, *F. nucleatum* and

P. gingivalis may collaborate to initiate neoplastic changes by triggering chronic inflammation.[46] Both *P. gingivalis* and *F. nucleatum* facilitate cancer cell invasion and metastasis by inducing the production of matrix metalloproteinases (MMP-2, MMP-13, and MMP-9), which play a role in pathological processes associated with extracellular matrix (ECM) degradation, including tumor invasion and metastasis.[46,47] Moreover, in addition to cytokines, reactive oxygen species generated by *F. nucleatum* infection contribute to cancer development by inducing mutations, genomic instability, and epigenetic changes. These cytokines can activate key transcription factors such as NF-κB and STAT3 in oral premalignant cells, subsequently promoting malignant processes such as proliferation, invasion, and metastasis.[46] Another potential mechanism explaining the contribution of *F. nucleatum* to oral carcinogenesis suggests that its infection promotes cell survival and migration.[17] In treatment-resistant patients, the oral microbiome plays a role in the prognosis of OSCC cases, and the low survival rate, aggressive nature of the tumor, and increased risk of metastasis may be associated with *F. nucleatum*.[21,39]

Treponema denticola

T. Denticola is a gram-negative anaerobic spirochete that constitutes a small fraction of the normal oral microbiota. It has been shown to possess various characteristics including motility, proteolytic activity, adhesion to epithelial cells, cytotoxicity, induction of bone resorption, and modulation of immune responses.[17] Being one of the most frequently associated spirochetes with periodontitis, *T. denticola* has also been implicated in the development of OSCC and oropharyngeal squamous cell carcinoma.[28,38,48] The association between *T. denticola* and OSCC is largely attributed to the effects of cytokines such as MMP-8 and MMP-9, which are linked to chronic inflammation, as well as its immunomodulatory capacity associated with various virulence factors including surface protein complexes, periplasmic flagella, and CTLP (chymotrypsin-like protease).[17,38] *T. denticola* has been reported to regulate the cell cycle in OSCC cells by activating the TGF-β signaling pathway and increasing the mRNA expression of TGF-β1, -β2, and -β3.[28] Additionally, it has been shown to enhance cell proliferation, particularly through a TGF-β1/Smad-dependent mechanism.[28]

Streptococcus spp.

Streptococcus anginosus is considered a significant factor in the development of head, neck, and esophageal cancers.[17,38,49,50] The frequent detection of *S. anginosus* in the cervical lymph nodes of OSCC patients suggests that damaged oral mucosa facilitates the colonization of *S. anginosus*, thereby accelerating bacterial drainage to the cervical lymph nodes.[17] The potential mechanism by which *S. anginosus* contributes to cancer development is based on its ability to enhance NO and COX-2 production, leading to DNA damage in infected tissues, which subsequently promotes carcinogenesis.[17] In addition to *S. anginosus*, other streptococcal species associated with OSCC include *Streptococcus constellatus, Streptococcus salivarius, Streptococcus gordonii*, and *Streptococcus parasanguinis*.[38]

Oral Micobiome and Oral Cancer

The fungal communities of the oral ecosystem are referred as the "oral micobiome." The species of *Candida*, which are found in approximately 80% of the population, are closely associated with OPMD and OSCC.[13,14,28,51,52] It is known that *Candida* is a member of the oral flora in healthy individuals, but can become pathogenic under certain conditions, particularly in immunocompromised patients leading to various opportunistic acute and chronic infections.[28,53] Oral candidiasis, caused by the overgrowth of *Candida* species (especially *C. albicans*), is the most common fungal infection of the oral mucosa.[53] Candidal infections contribute to the development of oral cancer by inducing pro-inflammatory cytokines and promoting the production of carcinogenic substances such as nitrosamines and acetaldehyde.[36,53] The increase in the number and density of Candida colonies can damage host cells, thereby promoting cancer development and potentially contributing to the progression of OPMDs into OSCC.[51,53] A systematic review on the relationship between candidal infections and oral leukoplakia, which has the highest incidence among OPMDs and carries a risk of malignancy, has shown that *Candida* may play a role in malignant transformation.[54] It has been found that the risk of developing oral cancer is three times higher in patients with *Candida* infection,[38] and the likelihood of *Candida* presence in the oral cavity of oral cancer patients is significantly higher compared to those without oral cancer.[28] Therefore, *C. albicans* has been considered an independent risk factor in the development of oral carcinoma.[54] The fact that chronic hyperplastic candidiasis exhibits a malignancy transformation rate ranging from 4.1% to 19.8%[52] also supports the relationship between *C. albicans* infection and the development of oral cancer.

Studies investigating the oral microbiome and cancer development report a wide range of microorganism loads with varying proportions. These significant differences are generally attributed to the lack of standardization in patient populations and microbiome research methods, as well as the heterogeneity in the studies. Older studies often focused on specific species and employed traditional methods such as bacterial culture, DNA-DNA hybridization, PCR, immunohistochemical staining, and denaturing gradient gel electrophoresis.[25] However, it has been reported that next-generation sequencing (NGS) shows higher sensitivity compared to these traditional methods. NGS technology has broad applications in understanding the ecology of microbial ecosystems and determining the role of bacteria in health and disease,[31,55] and it offers significant advantages such as high efficiency and the absence of the need for targeting specific taxa.[55] Since NGS technologies have shorter read lengths, it is necessary to carefully select appropriate 16S rRNA regions for the detection of a broad and diverse range of bacteria.[56] Among the nine hyper-variable regions, the V3-V4 regions have the most significant impact on the identification of bacterial communities.[21,56,57] Next-generation DNA sequencing systems allow for highly accurate and ultra-fast sequencing. The microbial genome sequences obtained through this method provide researchers with exceptionally rich and unique information that cannot be obtained by any other experimental technique.[55,58] This method helps in the comprehensive understanding of the functional dynamics of microbial communities, and thus, it can offer a new perspective on microbial pathogenesis, provide detailed characterization of microorganisms involved in the cancer development process, and be used to identify appropriate bacterial taxa for diagnosis or risk assessment.[57]

CONCLUSION

In conclusion, although certain species within the oral flora are associated with oral cancer, studies have shown that changes in the oral microbiome occur before carcinogenesis.[57] The findings suggest that the oral microbiome plays a significant role in the complex pathogenesis of oral cancer; however, various contributing factors combine to influence the disease process. Therefore, due to the complexity of the conditions related to the microbiome, no single pathogen can be held responsible for the formation of carcinogenesis.[37] A deeper understanding of the oral microbiome is expected to not only aid in the development of future research and clinical applications, but also facilitate the identification of new strategies for the diagnosis, treatment, and prevention of oral cancer. Additionally, it may pave the way for the creation of personalized treatment approaches, such as the use of probiotics and prebiotics.

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Implants and Autoimmune Diseases

Implantlar ve Otoimmün Hastalıklar

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ABSTRACT

Osseointegration describes the process by which dental implants integrate and become fixed within bone. This process occurs following the placement of the implant into the bone and is characterized by the direct contact between the implant and the surrounding bone. Osseointegration is critical for the long-term stability and durability of implants.

Autoimmune diseases, particularly their effects on bone metabolism, can have an impact on osseointegration. In autoimmune diseases, immune responses can alter bone remodeling. This can negatively affect the osseointegration process, increasing the risk of implant failure.

For instance, autoimmune diseases such as Sjögren's syndrome, systemic lupus erythematosus, and systemic sclerosis are associated with dry mouth, mucosal inflammation, and periodontal diseases. As a result, bone loss may occur around dental implants.

However, it has been shown that dental implants can successfully osseointegrate in individuals with autoimmune diseases. Therefore, patients considered for implant treatment should be evaluated, individually taking into account the status and management of their autoimmune conditions. Additionally, regular follow-ups and maintaining proper oral hygiene after implant placement can enhance the success of the osseointegration process.

Keywords: *Dental implants, osseointegration, autoimmune diseases, oral mucosal diseases*

ÖZ

Osseointegrasyon, dental implantların kemikle bütünleşerek sabitlenmesi sürecini tanımlar. Bu süreç, implantın kemik içine yerleştirilmesini takiben gerçekleşir ve implantın çevresindeki kemik ile doğrudan temas kurmasıyla karakterizedir. Osseointegrasyon, implantların uzun vadeli stabilitesi ve dayanıklılığı için kritik öneme sahiptir.

Otoimmün hastalıkların, özellikle kemik metabolizması üzerindeki etkileri, osseointegrasyon sürecini etkileyebilir. Otoimmün hastalıklarda, bağışıklık sistemi yanıtı anormal şekilde aktive olabilir ve kemik remodelleme süreçlerini değiştirebilir. Bu durum, implantın kemikle bütünleşme sürecini olumsuz etkileyebilir ve implantın başarısız olma riskini artırabilir.

Örneğin, Sjögren sendromu, sistemik lupus eritematozus ve sistemik skleroz gibi otoimmün hastalıklar ağız kuruluğu, mukozal inflamasyon ve periodontal hastalıklar ile ilişkilidir. Buna bağlı olarak dental implantların çevresinde kemik kayıpları meydana gelebilir.

Ancak, otoimmün hastalığı olan bireylerde dental implantların başarılı bir şekilde osseointegre olabileceği gösterilmiştir. Bu nedenle, implant tedavisi düşünülen hastaların, otoimmün hastalıklarının durumunu ve tedavi planlamasını dikkate alarak implant tedavisine uygunlukları değerlendirilmelidir. Ayrıca, implant sonrası düzenli kontroller ve uygun ağız hijyeni sağlanarak osteointegrasyon sürecinin başarısı artırılabilir.

Anahtar Kelimeler: *Dental İmplantlar, osseointegrasyon, otoimmün hastalıklar, oral Mukozal Hastalıklar*

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INTRODUCTION

The importance of scientifically validated dental implant therapy is steadily increasing. Dental implants are frequently used in edentulous patients to ensure prosthetic stability and maintain oral health. The presence of sufficient bone quality and volume, as well as general health influence implant success.

Over the past two decades, increased life expectancy has led to a continuously growing elderly population and, consequently, an expansion of the medically at-risk group.[1] In this age group, the prevalence of chronic diseases such as cardiovascular disease, diabetes, hypertension, autoimmune disorders, and cancer has risen. These conditions may serve as relative contraindications during implant placement. Among these medical conditions, a subset of autoimmune diseases poses specific risks for oral mucosal health.

Autoimmune diseases are characterized by an abnormal immunological response to autoantigens, leading to organ-specific or systemic inflammatory tissue destruction. The hallmark features of autoimmunity include the presence of circulating T cells, autoantibodies, and chronic inflammation.

Although the exact etiology of autoimmune diseases remains largely unknown, genetic, endocrinological, and environmental factors such as diet, lifestyle, and exposure to infections are believed to play a role in their development. It is estimated that autoimmune diseases affect approximately 3% to 5% of the global population and occur more frequently in women. However, the underlying reason for this gender disparity remains unclear.[2]

In individuals with autoimmune diseases, wound healing and osseointegration may be adversely affected due to alterations in the immune system. Although many conditions in medically compromised patients are still considered as risk factors for dental implant prognosis, there are only a few absolute contraindications for this treatment modality. [3]

The aim of this article is to review, the potential risks and complications that can affect the outcomes of dental implant therapy in patients with autoimmune diseases.

DISEASES

Oral lichen planus

Oral lichen planus (OLP) is a chronic mucocutaneous inflammatory disease that can affect the skin and/or mucous membranes.[4] The etiology of OLP remains unclear; however, it is thought to involve a cell-mediated immune dysregulation triggered by genetic and environmental factors. Secondary contributing factors may include local irritants (such as metal dental restorations, trauma, smoking, and alcohol consumption), systemic diseases (including diabetes, hypertension, and anxiety), and the use of certain medications (such as antimalarials, antihypertensives, diuretics, and nonsteroidal anti-inflammatory drugs).[5] OLP is more commonly observed in women aged 40–60, with a reported global adult prevalence of approximately 1.01%.[6]]. Due to its 1.40% risk of malignant transformation, close follow-up is essential.[7] While a high prevalence of OLP has been reported in patients with hepatitis C infection in Japan and the Mediterranean, no such association has been observed in France and the United States.[8]

It is recommended that dental implant procedures be performed during the remission phase of OLP.[9]

Regular follow-up is crucial not only for the early diagnosis and treatment of conditions such as peri-implant mucositis and peri-implantitis, but also for the timely detection of malignant transformation. Delayed diagnosis of peri-implantitis may compromise the long-term success of the implant, while diagnostic delays in malignant lesions can significantly increase the malignancy associated mortality and morbidity.[9]

In a systematic review conducted by Moya et al. in 2020, the implant survival rate in patients with OLP was reported to be 93.88% and this figure is not statistically significant when compared to healthy individuals. The review emphasizes the importance of regular follow-up and oral hygiene practices in maintaining these high survival rates.[10] The same review also recommends a prophylactic glucocorticoid (deflazacort) regimen for implant placement in OLP patients: 30 mg of glucocorticoid (deflazacort) for two days prior to the procedure, 15 mg of glucocorticoid (deflazacort) daily for three days following the procedure, and 7.5 mg of glucocorticoid (deflazacort) daily for the subsequent three days.[10]

In a study comparing the marginal bone loss around dental implants placed in patients with active OLP, controlled OLP (receiving systemic corticosteroids) and healthy individuals, it is reported that bone loss is significantly higher in the active OLP group (2.53 ± 0.44 mm) compared to the controlled OLP group (0.75 ± 0.56 mm) and the healthy group (0.79 ± 0.73 mm).[11]

In a systematic review published by Chrcanovic et al. in 2020, the five-year implant failure rate in patients with OLP was reported to be 2.7%. The same publication noted that in OLP patients who developed squamous cell carcinoma, the implant failure rate was 90.6%; however, in none of these cases was osseointegration lost. Instead, the implants were removed along with the tumor.[9]

Patients with OLP can be rehabilitated with dental implants. Potential risks and complications that may affect treatment outcomes should be carefully evaluated by the clinician and clearly communicated to the patient.[10]

Sjögren's syndrome

Sjögren's syndrome (SS) is a chronic autoimmune disorder characterized by dry eyes and dry mouth due to an immune-mediated attack on the body's exocrine glands. SS is more prevalent in women than in men and is considered to be the second most common rheumatic autoimmune disease after rheumatoid arthritis.[12] Medications commonly used by this patient group, such as hydroxychloroquine, cyclosporine, and corticosteroids, should be taken into consideration during treatment planning.

SS has numerous effects on oral health, including xerostomia (dry mouth) due to reduced salivary flow, widespread dental caries, chronically inflamed mucosa, hypertrophic salivary glands, chronic candidiasis, angular cheilitis, increased plaque accumulation, and difficulties in swallowing and using prostheses. Because of their high susceptibility to dental caries, SS patients tend to experience tooth loss at an earlier age compared to the general population. Dental implants represent a prominent treatment option for SS patients who struggle with removable prostheses due to dry and sensitive oral mucosa.[13]

In a prospective cohort study published by Maarse et al. in 2022, 37 implants were placed in 17 patients with SS, and 26 implants were placed in 17 patients without SS for comparison. After 18 months of follow-up, implant survival was reported as 100% in the SS group and 96.2% in the control group. Marginal bone loss was observed to be 1.10 ± 1.04 mm in SS patients and 1.04 ± 0.75 mm in the control group. No statistically significant difference was found between the two groups in terms of clinical outcomes. Despite similar probing depths, SS patients demonstrated stronger signs of peri-implant soft tissue inflammation compared to non-SS patients. These inflammatory findings were suggested to be associated with decreased salivary flow in SS patients and the consequent reduction in the oral cavity's self-cleansing ability.[12]

Another review evaluated a total of 712 implants placed in 186 patients. Over a mean follow-up period of 72.5 ± 59.2 months, a failure rate of 4.1% was reported. Most implant failures were noted to occur within a few months following the surgical procedure. Consequently, due to the relatively low failure rate, dental implant therapy can be considered as a valid treatment option for patients with SS; however, the possibility of increased peri-implant bone loss compared to the general population should be taken into account.[13]

Rheumatoid arthritis

Rheumatoid arthritis (RA) is a chronic systemic disease that leads to cartilage damage and bone destruction. RA may be accompanied by comorbidities involving the cardiovascular, respiratory, hepatic, muscular, and skeletal systems.[14] This condition is commonly observed in individuals with the HLA-DR4 genotype. In RA patients, connective tissue disorders affecting the soft and hard tissues surrounding teeth and implants may also be present.[15] Although the pathogenesis and exact mechanism of RA remain unclear, several molecular factors that modulate its progression have been identified. At the molecular level, a range of cytokines and cyclooxygenase enzymes are known to trigger the inflammatory process. Tumor necrosis factor-alpha (TNF-α), interleukin (IL)-1β, and IL-6 have been reported to play significant roles in disease progression.[14]

In a study published by Alenazi et al. 3 groups of patients, each consisting of 14 individuals, were analyzed. The first group included systemically healthy individuals, the second group consisted of patients with only RA, and the third group included patients with RA accompanied by another connective tissue disease (7 diagnosed with systemic sclerosis, 4 with Sjögren's syndrome, and 3 with dermatomyositis). Bleeding on probing was found to be significantly higher in the second and third groups compared to the first group. Additionally, in patients with RA and a secondary connective tissue disorder, levels of IL-6 and TNF-α in peri-implant crevicular fluid were reported to be higher than in patients with RA alone and in healthy individuals.[14]

In a prospective study comparing implant survival rates between RA and non-RA patients, El-Sherbini et al. reported no significant differences between the two groups.[16]

A systematic review examining 12 studies on implant placement in RA patients reported a mean survival rate of 97.2% (353 out of 363 implants) after an average follow-up period of 50.8 months. These findings underscore the importance of close clinical monitoring in patients with RA.[2]

Systemic lupus erythematosus

Systemic lupus erythematosus (SLE) is a chronic, autoimmune, multisystemic disease with a wide spectrum of clinical manifestations, affecting joints, tendons, kidneys, skin, blood vessels, as well as major organs such as the heart, lungs, and brain.[17] It has been reported that oral mucosal involvement occurs in approximately 40% of patients with SLE.[18]

SLE is more common in women and is typically diagnosed between the ages of 20 and 40.[19] Current treatment approaches include antimalarial agents such as hydroxychloroquine, nonsteroidal anti-inflammatory drugs, glucocorticoids, immunosuppressive agents (cyclophosphamide, methotrexate, azathioprine, mycophenolate mofetil), and biologics such as belimumab and rituximab[20] As with many autoimmune diseases, the primary goal in managing SLE is to achieve disease remission or maintain low disease activity without flares.[17] Before prescribing new medications, a comprehensive medical consultation should be conducted to avoid organ damage and potential drug interactions.

Before initiating implant treatment, the possibility of avascular necrosis (osteonecrosis) due to steroid use, as well as potential reductions in bone quality and/or quantity, should be considered.[18]]. The femur is reported to be the most commonly affected site of avascular necrosis resulting from interrupted blood supply to the bone. The prevalence of symptomatic avascular necrosis ranges from 0.8% to 33%, while asymptomatic avascular necrosis has been reported in 29% to 45% of patients with systemic lupus erythematosus (SLE).[21] The mandible, due to its compact structure and limited vascularity, is also considered a susceptible site for necrosis.

Nevertheless, a separate systematic review examining the success of implant therapy in SLE patients reported a 100% implant survival rate.[18] In a cross-sectional study conducted on both SLE patients and systemically healthy individuals, no significant differences were found between the two groups in terms of periodontal parameters.[22]

Due to the use of corticosteroids and immunosuppressive medications, patients with SLE may have an increased susceptibility to infections. Therefore, surgical antibiotic prophylaxis should be considered in such cases.

Systemic sclerosis

Systemic sclerosis, an autoimmune disease, affects blood vessels and connective tissues through a series of pathophysiological processes including obstructive vasculopathy in small vessels, fibroblast inflammation, and subsequent immune dysregulation, ultimately resulting in the accumulation of extracellular matrix. The heart, lungs, kidneys, gastrointestinal tract, mucosa, and skin may be involved in the disease process.[23–25] Excessive collagen deposition in the skin and perioral tissues can lead to restricted mouth opening due to involvement of the orbicularis oris muscle.[26] Fibrosis of the salivary glands reduces salivary flow (xerostomia), impairing its antibacterial activity and buffering capacity, thereby contributing to dental erosion, caries, and periodontal disease. As a result, the use of mucosa-supported prostheses, oral hygiene practices, and dental treatments become increasingly difficult.[27,28]

In a systematic review published in 2023, implant survival rates were reported as 100% in case reports and 89.2% in case series. The review indicated that implant survival does not appear to be significantly affected by systemic sclerosis in patients who maintain good oral hygiene. The same publication also suggested that the use of short implants may serve as a viable alternative during implant surgery to facilitate manipulation in cases where mouth opening is restricted due to fibrosis.[29]

Crohn's disease

Crohn's disease is a progressive condition characterized by chronic inflammation of the gastrointestinal tract, which may also involve the oral cavity. It can affect any segment of the gastrointestinal system. In a typical clinical presentation, patients seek medical attention with complaints of abdominal pain, chronic diarrhoea, weight loss, and fatigue. The primary goal of current treatment strategies is to prevent complications and halt disease progression.[30] The prevalence of Crohn's disease is reported as 322 per 100,000 individuals in Europe, 319 per 100,000 in Canada, and 214 per 100,000 in the United States.[31]

In individuals with Crohn's disease, inadequate bone formation around implants may occur due to nutritional deficiencies and autoimmune inflammatory processes at the surgical site.[32]

In their study, Peron et al. reported successful osseointegration following the placement of implants measuring 11.5 mm in length and 3.75 mm in diameter. No signs of peri-implantitis were observed during the 2-year follow-up period. [33]

Further prospective clinical studies are needed to draw definitive conclusions regarding the effects of Crohn's disease on implant therapy.

CONCLUSION

It is evident that autoimmune diseases and their treatments can significantly influence the outcomes of implant therapy. Dental implant placement in individuals with autoimmune disorders requires special attention. Due to the inherent nature of these diseases characterised by immune system dysregulation, chronic inflammatory processes, and the use of immunosuppressive therapies implant success may be directly affected. According to the literature, each patient's individual immune status, systemic medication use, and tissue healing capacity should be carefully considered, and consultation with medical specialists is strongly recommended.

In this context, a multidisciplinary approach should be adopted when planning dental implants for individuals with autoimmune diseases. Patients' systemic conditions must be thoroughly evaluated, and long-term follow-up is imperative. Future large-scale clinical studies will contribute to the development of more specific clinical approaches aimed at improving implant success rates in this patient population..

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