

Assessment of Oral Disease Burden Using a Cluster Analysis in Dentistry

Diş Hekimliğinde Kümeleme Analizi Kullanılarak Ağız Hastalıkları Yükünün Değerlendirilmesi

Burcu AKSOY¹

¹ İstanbul University-Cerrahpaşa, Institute of Postgraduate Education, Department of Health Management, İstanbul, Türkiye

Zehra Özge ÇANDERELİ²

² İzmir Katip Celebi University, Faculty of Economics and Administrative Sciences, Department of Health Management, İzmir, Türkiye

Tuğba Emine BEYHAN³

³ Düzce University, Faculty of Business Administration, Department of Health Management, Düzce, Türkiye

Şükrü Can AKMANSOY⁴

⁴ Marmara University, Faculty of Dentistry, Department of Prosthodontics, İstanbul, Türkiye

Sertaç SİRMA⁵

⁵ Marmara University, Faculty of Dentistry, IT Director, İstanbul, Türkiye

Meral YAY⁶

⁶ Mimar Sinan Fine Art University, Faculty of Arts and Sciences, Department of Statistics, İstanbul, Türkiye

Ümit KARAÇAYLI⁷

⁷ Health Sciences University, Gülhane Faculty of Dentistry, Department of Oral and Maxillofacial Surgery, Ankara, Türkiye

Farida FORTUNE⁸

⁸ Queen Mary University of London, Faculty of Medicine and Dentistry, Centre for Oral Immunobiology and Regenerative Medicine, London, United Kingdom

Gonca MUMCU⁹

⁹ İstanbul Okan University, Faculty of Dentistry, Department of Oral and Maxillofacial Radiology, İstanbul, Türkiye

Geliş Tarihi/Received 16.07.2024

Revizyon Talebi/Revision Requested

25.07.2024

Son Revizyon/Last Revision

22.08.2024

Kabul Tarihi/Accepted

09.09.2024

Yayın Tarihi/Publication Date

21.10.2025

Sorumlu Yazar/Corresponding author:

Burcu Aksoy

E-mail: aksyburcu@gmail.com

Cite this article: Aksoy B, Çandereli ZÖ, Beyhan TE, Akmansoy ŞC, Sırma S, Yay M, Karacaylı Ü, Fortune F, Mumcu G. Assessment of Oral Disease Burden Using a Cluster Analysis in Dentistry. *Curr Res Dent Sci.* 2025;35(4):307-311.

ABSTRACT

Objective: This study aimed to identify homogeneous groups for Oral Disease Burden (ODB) with age through the K-Means cluster analysis in dentistry.

Methods: In this retrospective study, 465 adult patients and 276 elderly patients treated at integrated students' clinics in a public dental school (F/M:381/360; 18-91 years) were included. The ODB score (0-5 points) was calculated through the presence of periodontal problems, dental caries, pulpitis, need of prosthetic treatment, and need of tooth extraction. Homogeneous groups for ODB severity were identified within the dataset by K-Means cluster analysis.

Results: The highest ratios of oral health problems were periodontal problems (94.0%) in young adult patients (cluster-1; n=201; 18-36 years; ODB: 2.92±1.14) and (87.4%) in adult patients (cluster-2; n=199; 37-55 years, ODB: 3.28±1.34) and need for prosthetic treatment (90.7%) in older adult patients (cluster-3; n=193; 56-70 years, ODB: 3.19±1.41) and (87.2%) in elderly patients (cluster-4; n=148; 71-91 years, ODB: 2.33±1.30). The highest ODB score was found in adult patients among four clusters. Older adult patients had elevated ODB score compared to that in elderly patients (P=.000).

Conclusion: Needs of different treatment protocols or complex treatments were determined according to ODB with age groups defined by K-Means cluster analysis. These results may provide clues for developing patient empowerment strategies to improve oral health status as well as work force planning in integrated student clinics in dental schools.

Keywords: Oral disease burden, treatment needs, cluster analysis, patient empowerment

ÖZ

Amaç: Bu çalışmanın amacı, diş hekimliğinde Ağız Hastalıkları Yüğü (AHY) için yaşa bağlı homojen grupları K-Ortalamlar kümeleme analizi ile belirlemektir.

Yöntemler: Bu retrospektif çalışmaya, bir kamu diş hekimliği fakültesinin entegre öğrenci kliniklerinde tedavi edilen 465 yetişkin hasta ve 276 yaşlı hasta (K/E: 381/360; 18-91 yaş) dahil edilmiştir. AHY skoru (0-5 puan); periodontal problemler, diş çürüğü, pulpitis, protetik tedavi ihtiyacı ve diş çekim ihtiyacı aracılığıyla hesaplanmıştır. AHY şiddeti için homojen gruplar veri seti içinde K-Ortalamlar kümeleme analizi ile belirlenmiştir.

Bulgular: Periodontal problemlerin en yüksek oranda genç yetişkin hastalarda (%94,0) (küme-1; n=201; 18-36 yaş; AHY: 2,92±1,14) ve yetişkin hastalarda (%87,4) (küme-2; n=199; 37-55 yaş, AHY: 3,28±1,34) görüldüğü, ileri yetişkin hastalarda (%90,7) (küme-3; n=193; 56-70 yaş, AHY: 3,19±1,41) ve yaşlı hastalarda (%87,2) (küme-4; n=148; 71-91 yaş, AHY: 2,33±1,30) ise protetik tedavi ihtiyacının ön planda olduğu belirlenmiştir. Dört küme arasında en yüksek AHY puanı yetişkin hastalarda görülmüştür. İleri yetişkin hastaların AHY puanı yaşlı hastalara göre daha yüksek bulunmuştur (P=.000).

Sonuç: K-Ortalamlar kümeleme analizi ile tanımlanan yaş gruplarıyla birlikte AHY'ye göre farklı tedavi protokolleri veya kompleks tedavilere ihtiyaçların olduğu belirlenmiştir. Bu sonuçlar, ağız sağlığı düzeyinin iyileştirilmesine yönelik hasta güçlendirme stratejisinin geliştirilmesine ve entegre öğrenci kliniklerindeki iş gücünün planlanmasına yönelik ipuçları sağlayabilmektedir.

Anahtar Kelimeler: Ağız hastalıkları yükü, tedavi ihtiyaçları, kümeleme analizi, hasta güçlendirme

INTRODUCTION

Since oral diseases are a global public health problem for health policies owing to their high frequencies, progressive nature and serious effects on general health status,^{1,2} evidence-based oral health data^{3,4} are needed to develop oral health policies,⁵⁻⁸ define risk groups, improve clinical outcomes^{3,4,7,9,10} and establish patient empowerment strategies.¹¹ In addition to public and private dental healthcare providers, dental schools are other elements to deliver dental healthcare and also dental education by providing real professional experience simulation for students.¹²



The ODB is an outcome measure which reflects the treatment needs of patients and the intensities of oral diseases. The ODB consists of four components regarding presence of periodontal problems, dental caries, need of prosthetic treatment, and need of tooth extraction.¹ Although age is accepted as the predisposing factor for poor oral health as well as unmet treatment needs, different age groups are defined as risk groups according to cut-off values in different studies.^{2,5,13} Therefore, it is necessary to identify patient groups with similar clinical characteristics or define associations among clinical manifestations.¹² These are essential while planning dental healthcare delivery and dental education.^{1,2}

At this point, a K-Means cluster analysis as a data mining application and an unsupervised learning algorithm could help us to understand the complex relations. It divides large datasets with "n" data points into "k" clusters.¹⁴ For example, this analysis could be a good option to predict diabetes patients¹⁵ as well as to identify patients with high periodontitis risk¹⁶ and nutrition-related pattern in adults with morbid obesity¹⁷ in health science studies.

Finally, the detailed information regarding both ODB and age groups is also needed for developing patient empowerment strategies and for designing clinical practice. Yet, the limited information is available about the ODB in the literature.¹ Therefore, this study aimed to identify homogeneous groups for ODB with age through the K-Means cluster analysis in dentistry.

METHODS

This retrospective study was performed by using anonymous data from Hospital Information Management System (HIMS) in a public dental school, Marmara University, Istanbul, Turkey. Data of 465 adult patients and 276 elderly patients (F/M:381/360; mean age: 51.72±18.78 years; 18-91 years) treated in students' integrated clinics between September 2018 and March 2020 were included in the study. While determining the sample size complete count method was used. Patients with missing data were not included in the study. Data regarding socio-demographic profile (age, gender, marital status), place of residence and treatment history of patients were used. The study was approved by the Ethics Committees of the Medical School of Marmara University (Date: January 8, 2021, Number: 09.2021.17).

Age and ODB were important two main variables in the study. Age is accepted a main predisposing factor for oral health^{1,2} in both prevalence and clinical studies.^{1,18,19} The study group covered a wide range of age groups (18-64 years and ≥65 years old). In literature, individuals between the ages of 18-64 years are considered as adults, and those aged ≥65 years as elderly.^{20,21} The health status of these two age groups differs markedly in terms of lifestyle, diet, general health risks, visits to the dentist, and access to services.¹⁹ This classification can reveal clinically important differences in the planning and implementation of dental services, as the groups may have different treatment needs.

In the calculation of ODB, the presence of periodontal problems, dental caries, need of prosthetic treatment, and need of tooth extraction were scored as "1" for each clinical manifestation whereas absence of the condition was scored as "0". Each clinical condition was given one point to calculate the total ODB score.¹ However, a patient's dental treatment process goes through many different pathways. A tooth with pulpitis is a serious condition that causes particularly severe toothache, cause to tooth extraction if left untreated. This leads to an increased oral disease burden.²² Therefore, incorporating pulpitis into the assessment may allow a

more comprehensive and accurate reflection of the total disease burden on oral health. In the present study, pulpitis was also included as a variable to assess the ODB for comprehensively evaluating the oral health. Finally, the total ODB score could vary between 1 and 5, with the highest score indicating the worst possible clinical situation.

Statistical Analysis

Data were analyzed by using SPSS 28.0 statistic program (IBM SPSS Corp., Armonk, NY, USA). Data were presented as "mean" and "standard deviation" whereas the categorical data were presented as "n" and "%". The Chi-square test was used to compare categorical variables. Kruskal Wallis test, one of the non-parametric analysis tests, was used to compare the adult and elderly groups. Statistical significance was accepted as $P < .05$. In addition, both K-Means cluster analysis and Receiver Operating Characteristic (ROC) curve analysis were performed to identify ODB-related age groups. K-Means cluster analysis as a common machine learning approach was used to evaluate complex relationships and determine relationships between variables.²³ This analysis helped to identify homogeneous groups together with ODB and age and minimized the intra-cluster differences in the study. The optimal number of clusters was determined using the Elbow Method and expert opinion was also consulted to validate the number of clusters. Finally, four clusters were developed according to the K-Means cluster Analysis.

ROC curve analysis provides a systematic way to predict cut-off values.²⁴ The area under the ROC curve can be considered as a measure of potentially predictive accuracy.²⁵ ROC curve analysis was performed to determine the cut-off value for age in edentulous patients.

RESULTS

In the study, 62.8% (n=465; 18-64 years; 39.83±12.94 years) were adult patients and 37.2% were elderly patients (n=276; ≥65 years; 71.75±5.04 years). The distribution of ODB components were presented according to age groups in Table 1 ($P = .000$). The ODB score was 3.11±1.29 in the adult patients and 2.72±1.40 in elderly patients. The highest ratios of oral health related problems were periodontal problems in the adult group (88.6%) and prosthetic treatment need (89.9%) in the elderly group. Dental caries (72.0%) and pulpitis (50.8%) were commonly seen in adult patients. Besides, half of patients needed of tooth extraction (adult: 51.0% and elderly: 56.5%) in both age groups.

Table 1. The profile of the study group

	Adult Patients (18-64 years) (n=465)		Elderly Patients (≥65 years) (n=276)	
	Mean	SD	Mean	SD
Age (Years)	39.83	12.94	71.75	5.04
Oral Diseases Burden Score	3.11	1.29	2.72	1.40
	n	%	n	%
Gender				
Female	247	53.1	134	48.6
Male	218	46.9	142	51.4
Total	465	100	276	100
Marital Status				
Married	313	67.3	208	75.4
Single	125	26.9	62	22.5
Unknown	27	5.8	6	2.2
Total	465	100	276	100
Oral Diseases Burden				
Periodontal Problems	412	88.6	154	55.8
Dental Caries	335	72.0	85	30.8
Pulpitis	236	50.8	110	39.9
Need of Prosthetic Treatment	230	49.5	248	89.9
Need of Tooth Extraction	237	51.0	156	56.5

K-Means Cluster Analysis

Since close associations were available between ODB score and age, the K-Means cluster analysis was performed to classify patient's oral health profile according to age groups. Four clusters were identified by the K-Means analysis ($P < .05$), without gender differences ($P = .881$) (Table 2).

The highest ODB score was observed in adult patients (cluster-2; $n = 199$; 37-55 years) whereas elderly patients (cluster-4; $n = 148$; 71-91 years) had the lowest ODB score. Young adult patients had lower the ODB score (2.92 ± 1.14) than those in adult patients (3.28 ± 1.34) ($P = .000$) (Table 2) (Figure 1).

Table 2. The profile of patients according to K-Means cluster analysis

	Cluster-1 Young Adult Patients (n=201)	Cluster-2 Adult Patients (n=199)	Cluster-3 Older Adult Patients (n=193)	Cluster-4 Elderly Patients (n=148)	P
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	
Age (years; range)	27.25±5.46 (18-36)	46.04±5.59 (37-55)	65.08±4.28 (56-70)	75.16±4.52 (71-91)	.000*
Oral Diseases Burden Score	2.92±1.14	3.28±1.34	3.19±1.41	2.33±1.30	.000*
	n (%)	n (%)	n (%)	n (%)	
Gender					
Female	106 (52.7)	100 (50.3)	102 (52.8)	73 (49.3)	.881
Male	95 (47.3)	99 (49.7)	91 (47.2)	75 (50.7)	
Oral Diseases Burden					
Periodontal Problems	189 (94.0)	174 (87.4)	135 (69.9)	68 (45.9)	.000**
Dental Caries	166 (82.6)	142 (71.4)	78 (40.4)	34 (23.0)	.000**
Pulpitis	91 (45.3)	110 (55.3)	104 (53.9)	41 (27.7)	.000**
Need of Prosthetic Treatment	50 (24.9)	124 (62.3)	175 (90.7)	129 (87.2)	.000**
Need of Tooth Extraction	91 (45.3)	104 (52.3)	125 (64.8)	73 (49.3)	.001**

*Kruskal-Wallis test, **Chi-square test

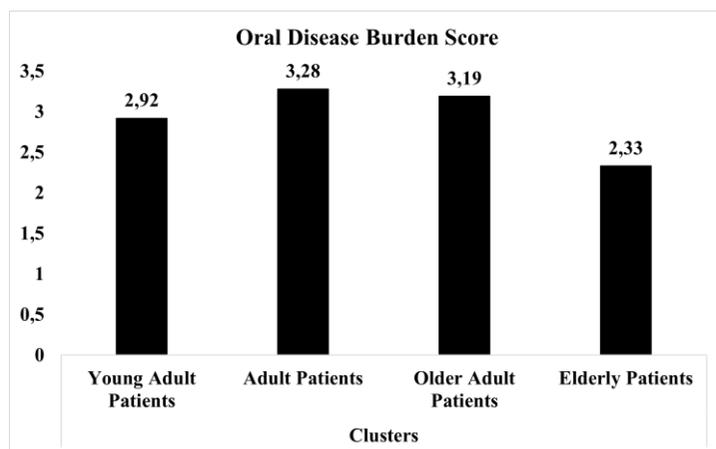


Figure 1. The distribution of ODB scores in clusters defined by ODB and age

The highest ratios of oral health related problems were periodontal problems (94.0%; 87.4%, respectively) and dental caries (82.6%; 71.4%) in both young adult patients (cluster-1; $n = 201$; 18-36 years) and adult patients comparing to those in other clusters (periodontal problems: 69.9% and 45.9% and dental caries: 40.4% and 23.0%) ($P = .000$; $P = .000$). However, the need for prosthetic treatment was significantly lower in young adult patients (24.9%) than adult patients (62.3%) ($P = .000$) (Table 2). The need for scaling and root planning (the initial step of periodontal treatment), and tooth filling were highest in young adult patients (93.0%; 83.6%) followed by adult patients (85.4%; 75.9%) ($P = .000$; $P = .000$).

Older adult patients (cluster-3; $n = 193$; 56-70 years) had elevated ODB score (3.19 ± 1.41 vs. 2.33 ± 1.30) compared to that in elderly patients (cluster-4; $n = 148$; 71-91 years) ($P = .000$). In elderly patients, the ratios of dental caries (23.0%) and pulpitis (27.7%) were around one fourth of the group whereas need of tooth extraction and periodontal problems were seen almost half of the group (49.3%, 45.9%). The ratios of all these clinical manifestations were higher in older adult patients (40.4%; 53.9%; 64.8%; 69.9% respectively) than elderly patients ($P = .000$; $P = .000$; $P = .000$ and $P = .001$ respectively) (Table 2).

Majority of patients in need for prosthetic treatment are both older adult patients (90.7%) and elderly patients (87.2%) (Table 2). The need for crowns (57.5%), partial dentures (45.6%) and temporomandibular joint treatments (50.8%) was higher in older adult patients compared to elderly patients (30.4%; 27.7%; 41.2%) ($P = .000$; $P = .001$; $P = .000$). On contrary, complete dentures were the most needed prosthetic treatment in elderly patients (57.4%) compared to older adult patients (38.9%) ($P = .001$).

ROC Curve Analysis

Patients who were edentulous and in need for complete dentures were older (72.9 ± 5.08 years) than the other patients who had natural dentition (69.34 ± 3.89 years) ($P = .000$). When the ROC curve analysis was performed, the cut-off value of age in elderly patients for edentulism was 69.5 years according to ROC curve analysis (AUC: 0.728) (Figure 2).

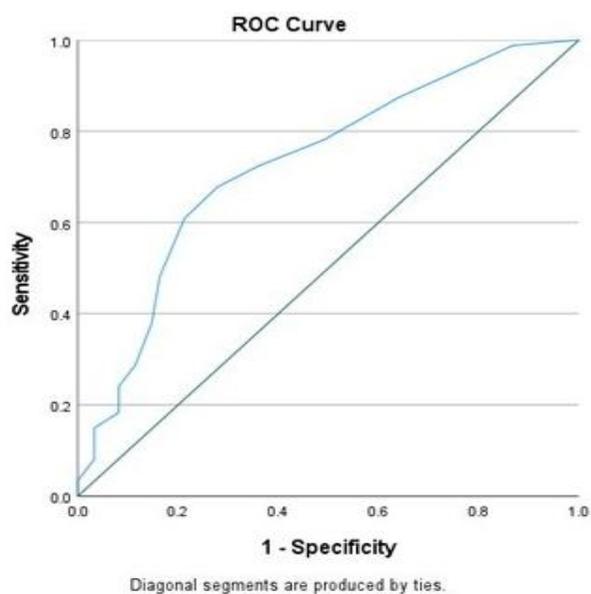


Figure 2. ROC curve of age cut-off point for edentulism

DISCUSSION

Nowadays, patient-centred care focusing on patients' needs and preferences could be though as essential points in dentistry.²⁶ Since dental schools give dental care service to population through dental students, they have important roles in improving oral health, giving oral health education and developing patient empowerment strategies in a population. Patient empowerment strategies for the sustainability of oral health are changing oral hygiene habits positively and understanding of unmet dental needs of patients.¹³ In addition, the assessment of evidence-based clinical data in HIMS of a public dental school provides information for planning of dental care delivery³ and clinical training curriculum of dental students.¹² In the present study, ODB reflecting treatment needs was examined in a

database extracted from HIMS from a public dental school. Age^{1,2} and ODB were main components of the K-Means cluster analysis for the study.

It was performed to define the homogeneous ODB profile with age in the study. The K-Means cluster analysis is popular in many fields such as medicine and business to define homogeneous groups.¹⁶ In this study, four clusters were developed through this analysis.

In this study, periodontal problems and dental caries are similarly the most common oral health problems in young adult patients (cluster-1). As predicted, untreated dental problems in the early stages of life continued to adulthood (cluster-2). Similarly, dental caries and periodontal problems are the most significant oral health burden²⁷ in studies performed in different countries.^{2,19,24,28-30}

Since they can be prevented by oral hygiene education and regular dental visits,^{2,29} patients should be educated to establish oral hygiene habits from childhood.^{13,26} Moreover, routine dental checkups are another important issue for both improving oral health and increasing oral health literacy.¹¹

The need of tooth extraction was observed over the half of older adult patients (cluster-3; 64,8%) and adult patients (cluster-2; 52,3%). A tooth with incurable dental and periodontal problems is extracted. Then, prosthodontic treatment need is inevitable to protect oral functions. Therefore, elevated oral disease burden could be predicted in these age groups

Majority of patients in older adult patients (cluster-3) and elderly groups (cluster-4) need prosthodontic treatments. If patient empowerment strategies and preventive applications are not performed in the early ages, improving oral functions and solving aesthetic problems could only be achieved by prosthodontic treatments.²²

In elderly patients aged ≥ 65 years in France, almost half of them (53%) needed dental prosthesis (53%) and tooth extractions (45.1%).⁶ Similarly, prosthetic treatment (62%) was the most needed treatment option in patient aged ≥ 70 years in Holland.³¹

In the study, the ODB score was found to be low in elderly patients as expected because 70 years of age was found to be cut-off value for being edentulous according to ROC curve analysis. Elderly are a vulnerable group who are socio-economically disadvantaged, have different systemic diseases and problems in accessing services due to decreases in their mobilities.^{5,32,33} Therefore, dentists should work in collaboration with other professional groups that are experts on aging.^{34,35} Additionally, the curriculum of dental schools should be updated to include gerodontology education.

The study gave some clues to develop patient empowerment strategies for patients treated in a public dental school located in Istanbul that has unique position to reflect the population. However, the main limitation of the study was that patient records were obtained from HIMS in a limited period.

CONCLUSION

Different treatment protocols or complex treatment needs were identified based on the ODB within the age groups defined by K-Means cluster analysis. These results may provide clues for developing patient empowerment strategies to improve oral health status as well as work force planning in integrated student clinics in dental schools.

Ethics Committee Approval: Approval was obtained from Marmara University Faculty of Medicine Ethics Committee (Date: January 8, 2021, Number: 09.2021.17)

Informed Consent: Since the study uses secondary data containing anonymized patient data, informed consent is not required.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – G.M, F.F.; Design – B.A., Z.Ö.Ç., Ş.C.A., S.S., G.M.; Supervision – G.M.; Resources – B.A., Z.Ö.Ç., T.E.B., Ş.C.A., S.S., M.Y., G.M.; Materials - B.A., Z.Ö.Ç., Ş.C.A., M.Y., G.M.; Data Collection and/or Processing - B.A., Z.Ö.Ç., Ş.C.A., M.Y., G.M.; Analysis and/or Interpretation - B.A., Z.Ö.Ç., M.Y., Ü.K., G.M.; Literature Search - B.A., Z.Ö.Ç., T.E.B., G.M.; Writing Manuscript – B.A., Z.Ö.Ç., T.E.B., Ş.C.A., M.Y., Ü.K., F.F., G.M.; Critical Review - B.A., Z.Ö.Ç., Ş.C.A., M.Y., Ü.K., F.F., G.M.

Conflict of Interest: The authors have no conflicts of interest to declare.

Financial Disclosure: This study was supported by Marmara University Scientific Research Projects Unit. Project Number: 10206. (Date: 16.02.2021-16.02.2022).

Etik Komite Onayı: Marmara Üniversitesi Tıp Fakültesi Etik Kurulu'ndan (Tarih: 8 Ocak 2021, Sayı: 09.2021.17) alınmıştır.

Hasta Onamı: Araştırmada anonimleştirilmiş hasta verilerini içeren ikincil verilerin kullanılması nedeniyle hasta onamı alınması gerekmemektedir.

Hakem Değerlendirmesi: Dış bağımsız.

Yazar Katkıları: Fikir - G.M, F.F; Tasarım - B.A., Z.Ö.Ç., Ş.C.A., S.S., G.M.; Denetim - G.M.; Kaynaklar - B.A., Z.Ö.Ç., T.E.B., Ş.C.A., S.S., M.Y., G.M.; Malzemeler - B.A., Z.Ö.Ç., Ş.C.A., M.Y., G.M.; Veri Toplama ve/veya İşleme - B.A., Z.Ö.Ç., Ş.C.A., M.Y., G.M.; Analiz ve/veya Yorum - B.A., Z.Ö.Ç., M.Y., Ü.K., G.M.; Literatür Taraması - B.A., Z.Ö.Ç., T.E.B., G.M.; Yazma - B.A., Z.Ö.Ç., T.E.B., Ş.C.A., M.Y., Ü.K., F.F., G.M.; Eleştirel İnceleme - B.A., Z.Ö.Ç., Ş.C.A., M.Y., Ü.K., F.F., G.M.

Çıkar Çatışması: Yazarlar, çıkar çatışması olmadığını beyan etmiştir.

Finansal Destek: Bu araştırma Marmara Üniversitesi Bilimsel Araştırma Projeleri Birimi tarafından desteklenmiştir. Proje Numarası: 10206. (Tarih: 16.02.2021-16.02.2022).

REFERENCES

- de Lucena EH, da Silva RO, Barbosa ML, de Araujo ECF, Pereira AC, Cavalcanti YW. Influence of socioeconomic status on oral disease burden: A population-based study. *BMC Oral Health*. 2021;21(1):608-615.
- Pekiner F, Gumru B, Borahan MO, Aytugur E. Evaluation of demands and needs for dental care in a sample of the Turkish population. *Eur J Dent*. 2010;4(2):143-149.
- Chiappelli F. Evidence-based dentistry: Two decades and beyond. *J Evid Based Dent Pract*. 2019;19(1):7-16.
- Oancea R, Amariei C, Eaton KA, Widstrom E. The healthcare system and the provision of oral healthcare in European Union member states: Part 5: Romania. *Br Dent J*. 2016;220(7):361-366.
- Chae S, Lee Y, Kim J, Chun KH, Lee JK. Factors associated with perceived unmet dental care needs of older adults. *Geriatr Gerontol Int*. 2017;17(11):1936-1942.
- Montal S, Tramini P, Triay JA, Valcarcel J. Oral hygiene and the need for treatment of the dependent institutionalised elderly. *Gerodontology*. 2006;23(2):67-72.
- Chhabra KG, Mulla SH, Deolia SG, Chhabra C, Singh J, Marwaha BS. Dental Informatics in India: Time to embrace the change. *J Clin Diagn Res*. 2016;10(3):12-15.

8. Damaskinos P, Koletsi-Kounari H, Economou C, Eaton KA, Widstrom E. The healthcare system and provision of oral healthcare in European Union member states. Part 4: Greece. *Br Dent J*. 2016;220(5):253-260.
9. Benning NH, Knap P. Hospital information systems. *Stud Health Technol Inform*. 2020;274:159-173.
10. Schleyer T, Mattsson U, Ni Riordáin R, et al. Advancing oral medicine through informatics and information technology: A proposed framework and strategy. *Oral Dis*. 2011;17(1):85-94.
11. Acuna Mora M, Sparud-Lundin C, Moons P, Bratt EL. Definitions, instruments and correlates of patient empowerment: A descriptive review. *Patient Educ Couns*. 2022;105(2):346-355.
12. Bakhshaei A, Ramachandran S, Brondani M. Teledentistry within oral health care providers' training: A scoping review. *Eur J Dent Educ*. 2024;28(2):631-44.
13. Zubiene J, Milciuviene S, Klumbiene J. Evaluation of dental care and the prevalence of tooth decay among middle-aged and elderly population of Kaunas city. *Stomatologija*. 2009;11(2):42-47.
14. Haraty RA, Dimishkieh M, Masud M. An enhanced k-means clustering algorithm for pattern discovery in healthcare data. *International J Distributed Sensor Networks*. 2015;11(6):615740.
15. Arora N, Singh A, Al-Dabagh MZN, Maitra SK. A novel architecture for diabetes patients' prediction using k-means clustering and svm. *Mathematical Problems in Engineering*. 2022;2022:1-9.
16. Ghassib IH, Batarseh FA, Wang HL, Borgnakke WS. Clustering by periodontitis-associated factors: A novel application to NHANES data. *J Periodontol*. 2021;92(8):1136-50.
17. Marquezin MCS, Chaves-Júnior SC, Rasera I, Jr., et al. Oral health and nutritional characteristics of adults with morbid obesity: A multivariate analysis. *Front Nutr*. 2020;7:589510.
18. National Institutes of Health. *Oral Health in America: Advances and Challenges*. Bethesda, MD: US Department of Health and Human Services, National Institutes of Health, National Institute of Dental and Craniofacial Research; 2021.
19. Petersen PE, Yamamoto T. Improving the oral health of older people: The approach of the WHO global oral health programme. *Community Dent Oral Epidemiol*. 2005;33(2):81-92.
20. World Health Organization. *Global Recommendations on Physical Activity for Health*. Geneva: World Health Organization; 2010.
21. World Health Organization. *Population Ageing-A Public Health Challenge, Information Fact Sheet*. Number 135. Geneva: World Health Organization; 1998.
22. Kojima Y, Sendo R. Maintaining tooth vitality with super minimally invasive pulp therapy. *Cureus*. 2022;14(9):e29712
23. Yoder Clark A, Blumenfeld N, Lal E, Darbari S, Northwood S, Wadpey A. Using k-means cluster analysis and decision trees to highlight significant factors leading to homelessness. *Mathematics*. 2021;9(17):2045-2058.
24. Institute of Medicine, National Research Council. ROC analysis: Key statistical tool for evaluating detection technologies. In: Joy JE, Penhoet EE, Petitti DB, eds. *Saving Women's Lives: Strategies for Improving Breast Cancer Detection and Diagnosis*. Washington, DC.: The National Academies Press; 2005:314-321.
25. Zhang Q, van Palenstein Helderma WH. Caries experience variables as indicators in caries risk assessment in 6-7-year-old Chinese children. *J Dent*. 2006;34(9):676-681.
26. Gaszynska E, Szatko F, Godala M, Gaszynski T. Oral health status, dental treatment needs, and barriers to dental care of elderly care home residents in Lodz, Poland. *Clin Int Aging*. 2014; 9:1637-1644.
27. Petersen PE, Bourgeois D, Ogawa H, Estupinan-Day S, Ndiaye C. The global burden of oral diseases and risks to oral health. *Bull World Health Organ*. 2005;83(9):661-669.
28. Ramraj C, Quinonez CR. Self-reported cost-prohibitive dental care needs among Canadians. *Int J Dent Hyg*. 2013;11(2):115-120.
29. Peres MA, Macpherson LMD, Weyant RJ, Daly B, Venturelli R, Mathur MR, et al. Oral diseases: A global public health challenge. *Lancet*. 2019;394(10194):249-260.
30. Al-Harbi F, El Tantawi M. Normative prosthodontic care need: does it impact the daily life of young Saudis with high level of oral diseases? A cross sectional study. *BMC Oral Health*. 2017;17(1):1-9.
31. Gerritsen P, Cune M, vand der Bilt A, Abbink J, de Putter C. Effects of integrated dental care on oral treatment needs in residents of nursing homes older than 70 years. *Spec Care Dentist*; 2015. 35(3):132-137.
32. Aida J, Takeuchi K, Furuta M, Ito K, Kabasawa Y, Tsakos G. Burden of oral diseases and access to oral care in an ageing society. *Int Dent J*. 2022;72(4):5-11.
33. Oliver D, Foot C, Humphries R. *Making our health and care systems fit for an ageing population*. London: The King's Fund; 2014.
34. Gil-Montoya JA, de Mello AL, Barrios R, Gonzalez-Moles MA, Bravo M. Oral health in the elderly patient and its impact on general well-being: A nonsystematic review. *Clin Interv Aging*. 2015;10:461-467.
35. Walji MF, Karimbux NY, Spielman AI. Person-centered care: Opportunities and challenges for academic dental institutions and programs. *J Dent Educ*. 2017;81(11):1265-1272.