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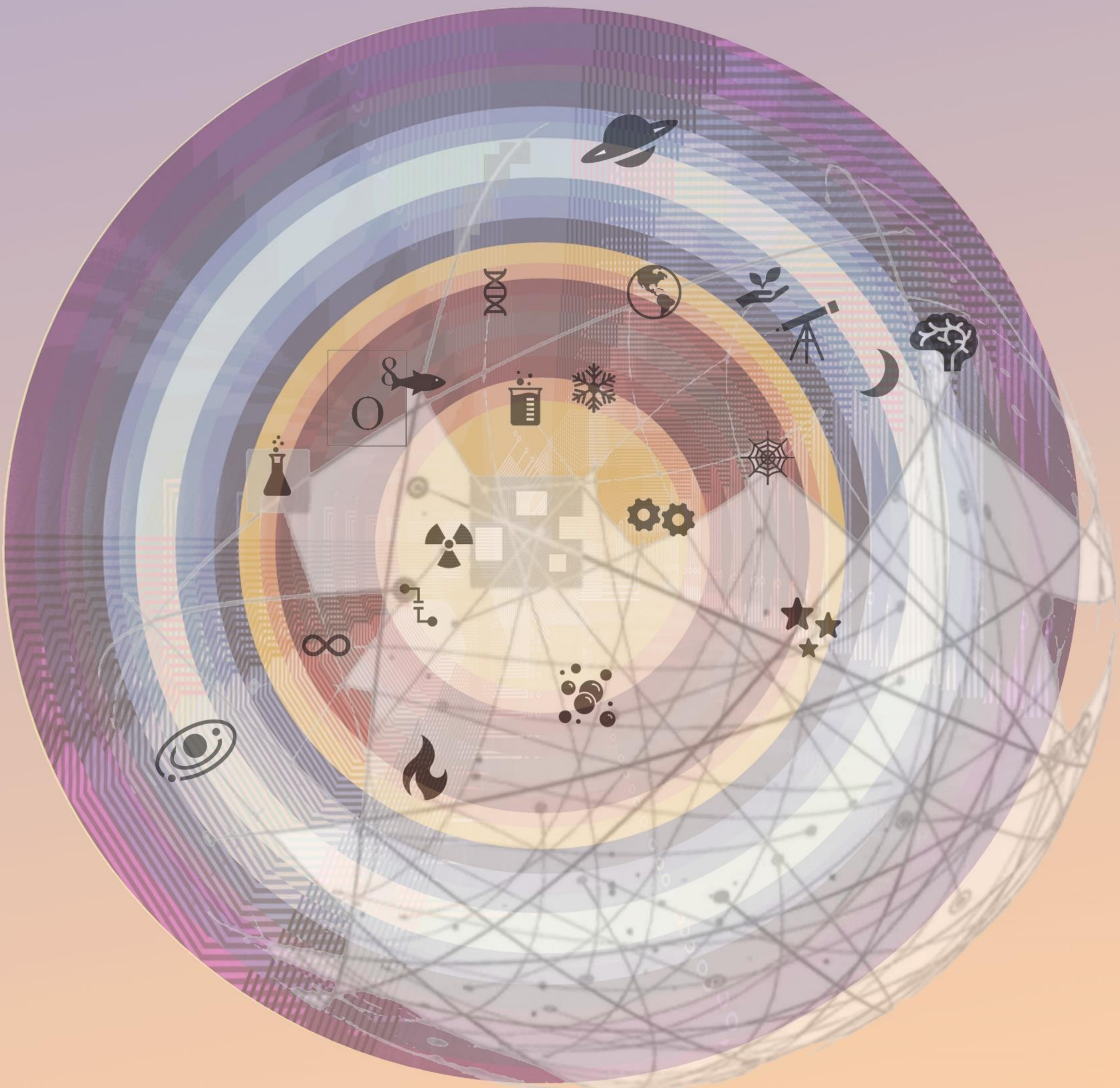

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Gama ile Işınlanmış Glisinamid Hidroklorür Toz Kristallerinin Elektron Paramanyetik Rezonans (EPR) İncelenmesi

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Anahtar Kelimeler:
Amino Asit Türevi,
Elektron Paramanyetik Rezonans,
Serbest Radikal.

Özet: Bu çalışmada, gama ışınları ile ışınlanmış Glisinamid Hidroklorür (GAHCl) toz kristallerinde oluşan serbest radikal yapılar, Elektron Paramanyetik Rezonans (EPR) spektroskopisi kullanılarak incelenmiştir. 20 kGy dozda ışınlanan örneğin EPR spektrumları kaydedilmiş ve ışınlama sonucu oluştuğu düşünülen $H_2N\dot{C}HCONH_2$ radikali tespit edilmiştir. Elde edilen EPR parametreleri (g-değeri: 2.0036, çizgi genişliği: 0.90 mT, aşırı ince yapı sabitleri: a_{CH} = 1.23 mT, a_N = 0.48 mT), simülasyon verileriyle uyumlu olup literatürdeki benzer glisin türevleriyle karşılaştırıldığında tutarlıdır. Ayrıca örneğin kimyasal ve biyolojik özellikleri kapsamlı bir şekilde araştırılmıştır. Bu sonuçlar, gama ışınlarının amino asit türevlerinde oluşturduğu yapısal değişikliklerin anlaşılması açısından önemli veriler sunmakta ve Glisinamid Hidroklorür'ün model bileşik olarak biyolojik ve farmasötik araştırmalarda kullanılabilirliğini göstermektedir.

Electron Paramagnetic Resonance (EPR) Study of Gamma-Irradiated Glycinamide Hydrochloride Powder Crystals

Keywords:
Amino Acid Derivative,
Electron Paramagnetic Resonance,
Free Radicals.

Abstract: In this study, free radical structures formed in gamma-irradiated Glycinamide Hydrochloride (GAHCl) powder crystals were investigated using Electron Paramagnetic Resonance (EPR) spectroscopy. EPR spectra of the sample irradiated with a dose of 20 kGy were recorded, and the $H_2N\dot{C}HCONH_2$ radical, presumed to have formed as a result of irradiation, was identified. The obtained EPR parameters (g-value: 2.0036, line width: 0.90 mT, hyperfine coupling constants: a_{CH} = 1.23 mT, a_N = 0.48 mT) were consistent with the simulation data and matched the values reported for similar glycine derivatives in the literature. Additionally, the chemical and biological properties of the sample were comprehensively investigated. These findings provide significant insights into the structural changes induced by gamma irradiation in amino acid derivatives and demonstrate the potential of Glycinamide Hydrochloride as a model compound in biological and pharmaceutical research.

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1. GİRİŞ

Elektron Paramanyetik Rezonans(EPR) spektroskopisi, serbest radikallerin yapısal özelliklerini incelemek ve kimliklerini belirlemek amacıyla kullanılan etkili tekniklerden biridir. Bu yöntem, amino asitler ve onların türevleri başta olmak üzere, gıda ürünleri ve ilaçlar gibi birçok farklı maddede oluşan hasar merkezlerinin tespiti için yaygın olarak tercih edilmektedir(Dicle ve ark. 2015; Sütçü, 2024; Osmanoğlu ve Sütçü, 2023; Sütçü ve Osmanoğlu, 2023; Sütçü ve ark., 2014; Osmanoğlu ve ark.,2017; Osmanoğlu, 2020).

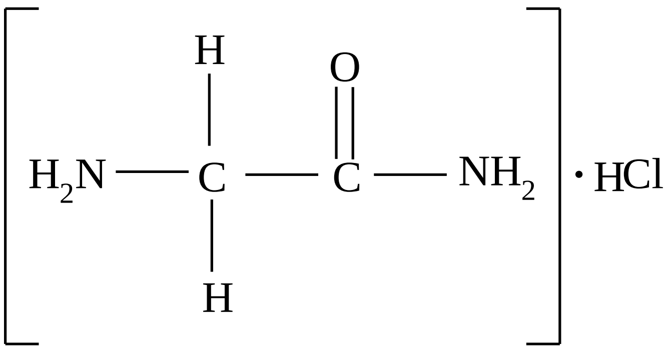
Glisin(Glycine), biyolojik sistemlerde önemli roller üstlenen temel bir amino asittir. Doğal proteinlerin yapı taşlarından biri olan glisin, pek çok hücresel işlevde görev alır ve çeşitli biyokimyasal süreçlerin temel bileşenlerinden biridir. Aynı zamanda, insan yaşamı için gerekli olan 20 temel amino asitten biri olarak kabul edilir. Glisinamid hidroklorür(GAHCl), glisinin amid türevi olup monohidroklorür tuzu şeklinde bulunur. Doğrudan biyolojik bir rolü olan doğal bir amino asit değildir, ancak türev bir bileşiktir. Glisin türevi olduğu için bazı biyokimyasal yollarla ilişkilendirilebilir(örneğin peptit ya da protein sentezi çalışmaları). Peptit sentezi ya da biyolojik tampon sistemlerinde kullanılabilir. Ayrıca, hücre zarından geçiş kolaylığı ve düşük toksisitesi sayesinde biyomedikal uygulamalarda tercih edilebilir. Gama ışınlamasıyla serbest radikal yapılar oluşturarak, Elektron Paramanyetik Rezonans(EPR) çalışmalarında da model madde olarak kullanılır. Bu yönleriyle glisinamid hidroklorür, hem farmasötik hem biyoteknolojik araştırmalarda önemli bir araçtır. Bu neden bu çalışmada Glisinamid Hidroklörürün gama ışınlaması sonucu oluşan paramanyetik bozuklukları belirlemek amaçlanmıştır.

2. MATERYAL VE YÖNTEM

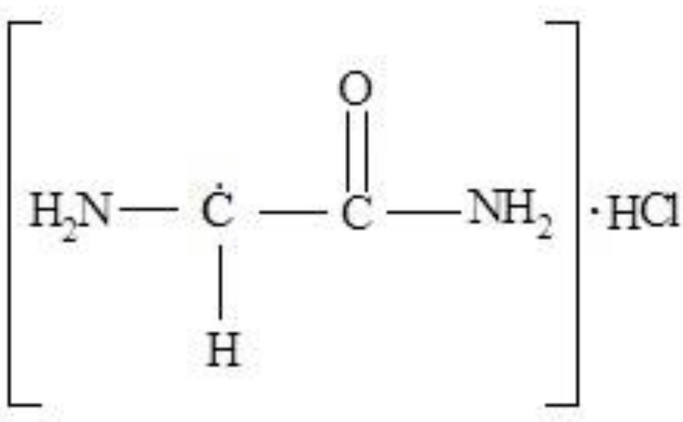
GAHCl nin toz örneği ^{60}Co γ(gama)-ışını kaynağı ile oda sıcaklığında 20 kGy doz oranında ışınlanmıştır. g değeri (spektroskopik yarılma faktörü) dipenhylpicrylhydrazyl(DPPH) örneği (g = 2.0036) ile karşılaştırılarak hesaplanmıştır. Spektrumlar simülasyon programı kullanılarak simüle edilmişlerdir(McKelvey 1987). Örnekte oluşan radikalin kararlı olduğu tespit edilmiştir. Elde edilen GAHCl'nin toz spektrumları, Bruker EMX081 spektrometresinde 2 mW mikrodalga gücünde modülasyon genliği ve 0.2 mT manyetik alan modülasyon frekansı 100 kHz değerlerinde spektrumlar kaydedilmiştir.

3. BULGULAR VE TARTIŞMA

Glisinamid hidroklorür, kapalı formülü $NH_2CH_2CONH_2 \cdot HCl$ ve molekül ağırlığı 110.54 g/mol dür. Kimyasal yapısı ise şekil 1'deki gibidir.



Şekil 1. Glisinamid Hidrokorür'ün molekül formülü



Şekil 2. Işınlanma sonucu oluşan Glisinamid hidroklorür radikali

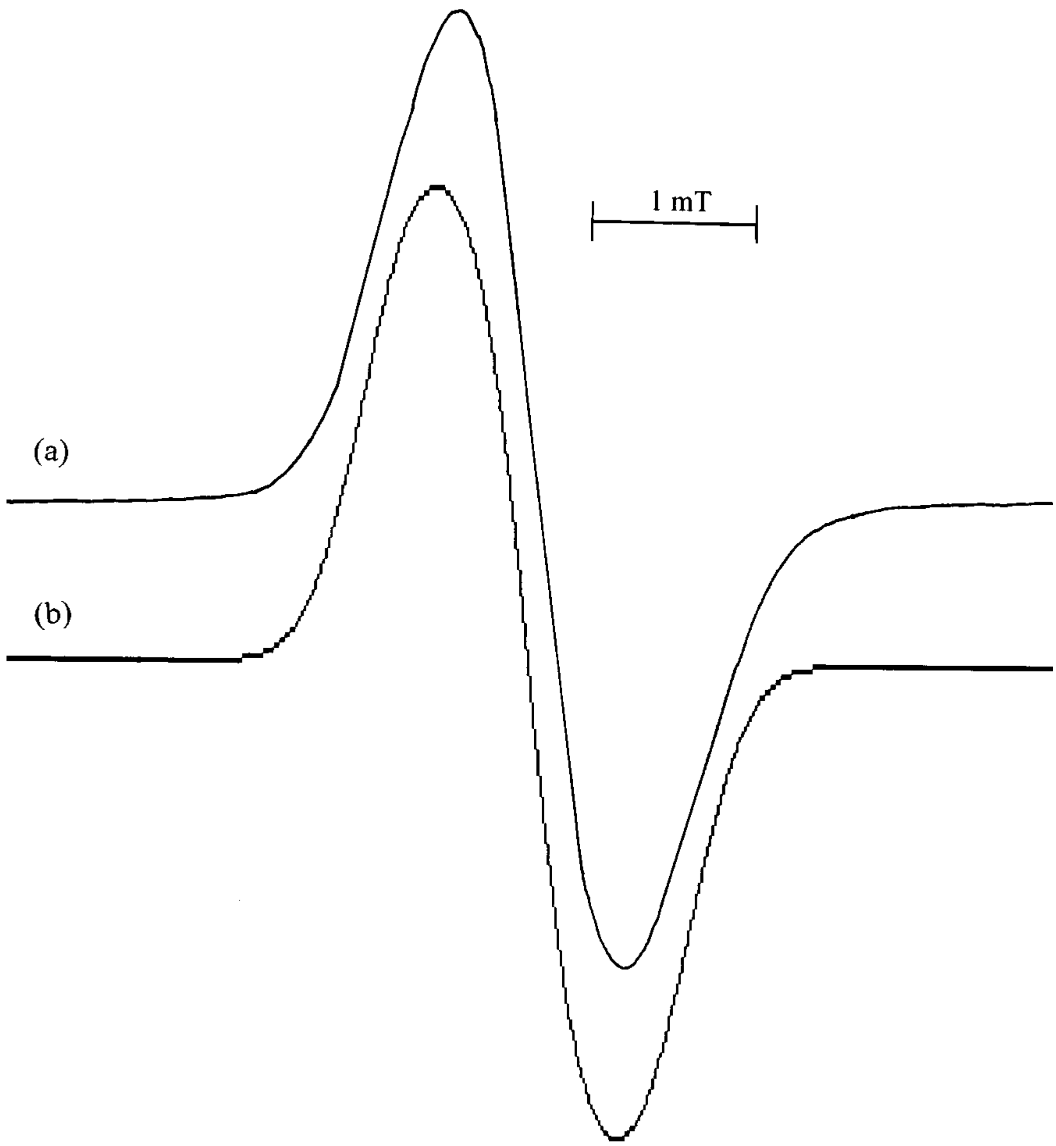
Toz halindeki Glisinamid hidroklorür (GAHCl), 20 kGy doz değerinde oda sıcaklığında gama- ışınları ile 10 saat ışınlandı ve EPR spektrumları kaydedildi. 20 kGy doz değerinde ışınlanmış GAHCl nin deneysel spektrumu Şekil 3 (a)'da verilmiştir. Şekilden de görüldüğü gibi GAHCl'nin EPR spektrumu geniş tek bir çizgi sergilemiştir.

Aşırı İnce Yapı(a.i.y.) etkileşme sabitleri $a_{CH=}$1.23 mT, a_N=0.48 mT kullanılarak simüle spektrum elde edilmiştir (Şekil 3 b). Deneysel spektrumla simüle spektrumun uyuştuğu görülmektedir.

Deneysel EPR spektrumundan g değeri g = 2.0036 olarak hesaplanmıştır. Çizgi genişliği ΔH 0.9 mT olarak ölçülmüştür. Şekil 3'te verilen geniş tek çizginin oluşum nedeni, eşlenmemiş elektronun merkezi karbon atomuna bağlı α protonu ve azot protonu ile etkileşmesidir. Çizgi genişliği çok büyük, yani α_{CH} değerine yakın, a_N değerinden oldukça büyük olması dolayısıyla aşırı ince yapı yarılmaları gözlenmemektedir. Benzer durum önceki çalışmalarda da gözlemlenmiştir (Başkan ve ark.2010; Şimşek ve ark. 2017).

Işınlama sonucu yapıda oluştuğu düşünülen radikal Şekil 2'de verilmiştir.

Glisin Hidroklorür, Gly-gly glisin, Gly-gly hidroklorür, L-Alanil glisin ve glisin L-Histidin gibi glisin türevi örneklerde g değeri 2.0031-2.0044 aralığında bulunmuştur (Osmanoğlu ve ark. 2017). GAHCl örneğinde bulunan g = 2.0036 değeri bu aralık değerleri içerisindedir. Glisin türevi örneklerin çoğunda karbon merkezli radikaller elde edilmiştir(Zincircioğlu ve ark. 2006; Başkan, 2008;Osmanoğlu, 2020; Aydın ve ark.,2008). Örneğimizde elde edilen $H_2N\dot{C}HCONH_2$ radikali de karbon merkezli bir radikaldir. Elde edilen sonuçlar glisin türevleriyle daha önce yapılan çalışmalarla uyumludur(Aydin, 2011; Zincircioğlu ve ark. 2006).



Şekil 3. a)Gama ışınları ile ışınlanmış Glisinamid hidroklorür toz kristalinin toz Kristal EPR spektrumu, b) Simüle edilmiş spektrum için a.i.y. değerleri a_{CH} = 1.23 mT, a_N= 0.48 mT ve çizgi genişliği ΔH= 0.90 mT olarak alınmıştır.

4. SONUÇ

Gama ışınları ile ışınlanmış Glisinamid hidroklorür toz kristalinde elde edilen EPR spektrumları kaydedilmiştir. Spektrumların incelenmesi ve McKelvey simülasyon programı yardımı ile yapıda oluştuğu düşünülen $H_2N\dot{C}HCONH_2$.HCl radikalin,$H_2NCH_2CONH_2$.HCl molekülünden H_α atomunun kopması sonucu oluştuğu düşünülmüştür. EPR ölçümlerinde spektroskopik parametreler belirlenmiştir.

Elde edilen veriler, ışınlama sonrası molekül yapısında meydana gelen değişikliklerin detaylı olarak anlaşılmasına olanak sağlamış ve gama ışınlarının amino asit türevlerinde oluşturduğu serbest radikal yapılar hakkında önemli bilgiler sunmuştur. GAHCl'nin bu bağlamda model bir bileşik olarak kullanılması, hem radyasyona maruz kalan biyolojik sistemlerin anlaşılması hem de radyasyonla oluşan yapısal değişimlerin moleküler düzeyde araştırılması açısından değerli sonuçlar ortaya koymaktadır. Bu çalışmanın bulguları, gelecekte yapılacak olan radyobiyolojik ve farmasötik uygulamalara ışık tutabilecek niteliktedir.

Sonuç olarak, canlıların yapı taşı olan amino asitler üzerinde gama ışının oluşturduğu yapısal bozukluğun cinsi ve yarı ömrünün belirlenmesi yaşayan canlılar için nedenli gerekli olduğu bu çalışmanın önemini göstermektedir.

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Original Article

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Van Gölü Havzasına Ait Doğal Süs Bitkileri Çeşitliliği

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Anahtar Kelimeler:
Süs bitkileri,
Van gölü havzası,
Doğal bitkiler,
Peyzaj, Aromatik bitkiler

Özet: Bu çalışmada Van gölü havzasına ait doğal süs bitkileri taksonomik olarak tespit edilmiştir. Araştırma alanından topladığımız 600 bitki örneğinin değerlendirilmesi sonucunda;50 familyaya ait 211 takson belirlenmiştir. Teşhis edilen bitkilerin: 77 adet aromatik, 7 adet herdemyeşil, 211'i estetik süs bitkisi olarak belirlenmiştir. 17 endemik tür tespit edilmiş olup endemizm oranı %11'dir. Ayrıca, bu çalışmada 21 tür hakkında ilk kez aromatik yönünden bilgi verilmiştir.

Diversity of Natural Ornamental Plants of Van Lake Basın

Keywords:
Ornamental plants,
Lake Van Basin,
Wild plants,
Landscape,
Aromatic plants

Abstract: The native ornamental plants of the Lake Van Basin have been identified taxonomically. As a result of evaluating 600 plant specimens collected from the research area, 211 species belonging to 50 families were identified. Among the diagnosed plants: 77 are aromatic**,** 7 are evergreen, and 211 were classified as ornamental plants with aesthetic value. The number of endemic species is 17, with an endemism rate of 11 %**.** In addition, this study provides, for the first time, information on the aromatic properties of 21 species.

1. GİRİŞ

1. GİRİŞ

Dünyada refah seviyesine bağlı olarak, insanların peyzaja ve peyzaj bitkilerine eğilimleri de artmaktadır. Bu nedenle insanlar, doğal koruma alanları oluşturmakta ve birçok doğal bitkiyi de çeşitli ihtiyaçları doğrultusunda kültüre almaktadırlar. Bitkiler aleminin yaklaşık 500000 doğal üyesi bulunmasına karşın, dünyada kültüre alınmış bitki sayısı dört milyon civarındadır ve hızla artmaktadır.

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İnsanlar tarafından, doğal veya kültür birçok bitki de aromatik ve estetik süs bitkisi olarak kullanılmaktadır. Kentsel ve kırsal peyzajda özellikle odunsu bitkiler, ağaçlar, çalılar ve aromatik bitkiler tarih boyunca insanların ilgisini çekmiştir. Mısır'da milattan önce binlerce kilometre uzaktan bitkiler taşınarak yeni alanlara dikilmiş ve dikim-bakım bilgileri ortaya konulmuştur (Ürgenç 1990, Asimgil,1993: Yildrimli, 1991)

Endüstrileşme ve kentleşmeye bağlı olarak peyzaja ve peyzaj bitkilerine de eğilimler artmaktadır. İnsanların aromatik ve süs bitkilerini kullanım eğilimlerinin yansımasını ortaya koyarken, diğer taraftan da bir gelişmişlik göstergesi olarak kabul edilmektedir (Tombul ve Altan, 1991; Şarer,1987;Şarer,1991).

Çok zengin bir floristik yapıya sahip olan Türkiye, yaklaşık 12000 bitki taksonu barındırmaktadır. Bunlarında yaklaşık 3500 taksonu Endemik bitkilerden oluşmaktadır. Türkiye bu zenginliği, engebeli coğrafyaya, zengin mikroklimaya ve kesişen fitocoğrafya özelliklerine borçludur (Güner ve ark.2000, 2002,Ekim 1997).

Van Gölü havzası, Türkiye'nin Doğu Anadolu bölgesinde yer almaktadır. Bu bölge, tür zenginliği ve endemik taksonlar açısından en çok bolluğa sahip bölgedir. Bölge, kullanılan faydalı bitkiler bolluğu açısından da önem arz eder (Ekim 1990). Araştırma alanı, kapalı havza özelliğinde olup, Davis'in Grid kareleri sistemine göre havzanın göl kıyıları B9 karesinde ve İran-Turan Fitocoğrafik bölgesinde yer almaktadır(Davis, 1965-1985;Davis & Tan, 1982;Davis, Mill, & Tan,1988). Van Gölü havzası,1645-4000 m arasında yüksekliğe sahiptir, Yıllık yağış miktarı300-600 mm civarındadır ve Akdeniz ikliminin etkisi altındadır (Öztürk, 1993).

Anadolu, kültür formların birçoğunun özellikle de kültür bitkilerinin doğal formların orijin merkezi olup, dünyanın özellikle gen ve genetik farklılaşma bölgelerinden biridir (Öztürk, 1990; Öğün,Altan,1992). Aromatik ve estetik birçok bitki barındıran havzada, Doğal yaklaşık1600 bitki taksonu, bunların da yaklaşık 200 taksonu Endemik olarak bilinmektedir (Demirkuş ve ark. 2001).

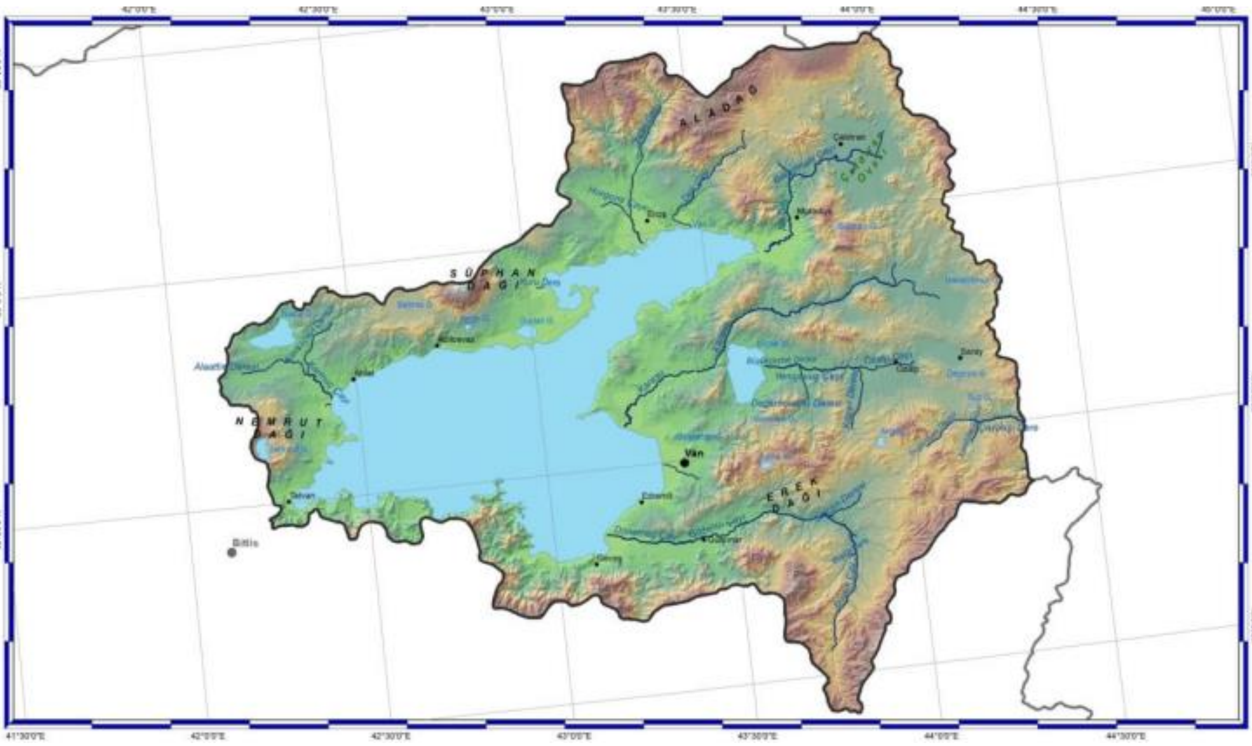
İnsanlar şimdi ve gelecekte, biyolojik zenginliklerden maksimum istifade edebilmek için bu tür araştırmalara ihtiyaç duyacaklardır. Bu araştırma ile, doğal estetik ve aromatik bitkiler belirlenerek, tarıma, peyzaja, floristik çalışmalara ve etnobotaniğe katkı sağlamak amaçlanmıştır.

2. MATERYAL VE YÖNTEM

Araştırma alanı Van Gölü kıyıları olarak bitki coğrafyası bakımından İran-Turan fitocoğrafik bölgesinde yer alır(Çetik, 1985). Davis'in Türkiye florası için uyguladığı grid (Coğrafık kare) sistemine göregöl kıyıları B9 karesinde yer almaktadır (Davis, 1985). Dağlık olan havza arazisi genellikle 1600-2500 metre yükseltilidir. Çevre dağlarının,dorukları 4000 metreyi aşar. Van Gölü yüzeyinin rakımı 1648-1650 metredir^ Erçek (1890m), Nazik (1870 m), Nemrut Gölü (2400m.) daha yüksektir. Van ilinin büyük kısmı ile, Bitlis'in Ahlat, Adilcevaz, Tatvan ilçeleri ve kısmen merkez ilçe havza sınırları içinde kalır (Anonymus,1971).

Emberger'in yaz kuraklığı indisine göre , araştırma alanında indis değeri Van için 5'den küçüktür. Ayrıca Van Meteoroloji İstasyonu'nda en az yağışların yaz mevsiminde kaydedilmesi ve toplam yaz yağışlarının 2000 mm'den düşük olması, bu sahanın Akdeniz ikliminin etkisi altında olduğunu gösterir (Öztürk, 1993; Öztürk,1994).

Bitki materyalleri, Van gölü havzasında (Şekil 1) gölün yakın çevresinden vejetasyon döneminde toplanmıştır. Toplanan materyaller kurutularak taksonomik teşhisleri flora eserlerinden yapılmıştır (Davis, 1965-1985; Davis ve Tan, 1982; Davis, Mill ve Tan,1988; Demirkuş ve ark., 2001). Floristik liste alfabetik düzende verilmiştir. Listede, Endemik, estetik, aromatik ve herdemyeşil özellikleri belirtilmiştir (Öztürk, 1990; Öztürk, 1990a; Özçelik, 1990; Öztürk ve Özçelik, 1991; Boynukara ve Öztürk, 1992; Öztürk ve Behçet, 1993; Öztürk, 1994; Öztürk, 2004; Öztürk, Yağmur ve Ölçücü, 2018; Öztürk ve Acar, 2019).



Şekil 1. Araştırma alanı Van gölü havzasının haritası.

3. BULGULAR VE TARTIŞMA

Araştırma alanından toplanarak taksonomik teşhisleri yapılmış bitkilerin listesi aşağıda sunulmuştur.

3.1. Van Gölü Havzasına Ait Doğal Süs Bitkilerin Floristik Listesi

1. ACERACEAE

1. *Acer negundo* L., Estetik

2. AMARYLLIDACEAE

2. *Ixiolirion tataricum* Herbert
3. ., Estetik

3. APIACEAE

4. *Eryngium billardieri* Delar, Aromatik, Estetik
5. *Ferula orientalis* L., Aromatik, Estetik
6. *Pimpinella corymbosa* Boiss., Aromatik, Estetik
7. *Prangos pabularia* Lindl. Aromatik, Estetik

4. ARACEAE

8. *Arum italicum* L., Estetik

5. ASTERACEAE

9. *Achillea biebersteinii* Afan., Aromatik, Estetik
10. *Anthemis tinctoria* L., Aromatik, Estetik
11. *Achillea vermicularis* Trın., Aromatik, Estetik
12. *Cota wiedemanniana* Fısch.&Mey.Endemik,Aromatik,Estetik
13. *Artemisia austriaca* Jacq.,Aromatik, Estetik
14. *Bellis perennis* L., Estetik
15. *Carduus nutans* L., Estetik
16. *Centaurea virgata* Lam., Estetik
17. *Centaurea depressa* M.Bieb., Estetik
18. *C. iberica* Trev., Estetik
19. *C. kurdica* Reichardt, Estetik
20. *Cichorium intybus* L., Estetik
21. *Cirsium arvense* Scop., Estetik
22. *Crepis sancta* L..,Estetik
23. *Echinops pungens* Trautv., Estetik
24. *E. orientalis* Trautv., Estetik
25. *Helichrysum plicatum* D.C., Aromatik, Estetik
26. *Inula helenium* L., Aromatik,Estetik
27. *Lactuca serriola* L .,Estetik
28. *Onopordum candidum* Nab., Estetik
29. *Scorzonera cana* Hoffm.,Estetik
30. *Senecio vernalis* Waldst.&Kit., Estetik
31. *Tanacetum balsamita* L., Aromatik, Estetik
32. *Taraxacum montanum* D.C. ., Aromatik,Estetik
33. *Tragopogon longirostris* Bısch., Aromatik,Estetik
34. *Tripleurospermum parviflorum* Pob.,Aromatik, Estetik
35. *Tanacetum kotschyi* Grierson,Aromatik,,Estetik
36. *Tussilago farfara* L., Estetik
37. *Xeranthemum annuum* L., Estetik

6. BERBERIDACEAE

38. *Bongardia chrysogonum* Spach., Estetik

7. BETULACEAE

39. *Betula pendula* Roth., Estetik

8. BORAGINACEAE

40. *Alkana orientalis* Boiss.,Estetik
41. *Anchusa azurea* Mıller.,Estetik
42. *Myosotis alpestris* F.W.Schmıdt, Estetik
43. *Nonea caspica* G.Don..,Estetik
44. *Rindera lanata* Bunge.,Estetik
45. *Rochelia disperma* Reıchb.,Estetik

9. BRASSICACEAE

46. *Crambe orientalis* L., Aromatik, Estetik

10. CAMPANULACEAE

47. *Campanula glomerata* L.,Estetik
48. *C. coriacea* Davis.,**Endemik**,Estetik
49. *C. stevenii* Bieb.,Estetik
50. *C. stricta* L.,Estetik

11. CAPPARACEAE

51. *Capparis ovata* Desf., Estetik, Herdemyeşil

12. CAPRIFOLIACEAE

52. *Sambucus nigra* L., Estetik

13. CARYOPHYLLACEAE

53. *Dianthus orientalis* Adams, Aromatik, Estetik
54. *Gypsophila bitlisensis* Bark, **Endemik** , Estetik
55. *Silene alba* Krause, Estetik

14. CHENOPODIACEAE

56. *Atriplex pungens* Trautv.,Estetik
57. *Chenopodium folisum* Aschers, Estetik
58. *Chenopodium botrys* L., Aromatik, Estetik

15. CRASSULACEAE

59. *Rosularia radiciflora* Boiss., Estetik
60. *Sedum album* L., Estetik

16. CUPRESSACEAE

61. *Juniperus excelsa* L.,Aromatik,Estetik,Herdemyeşil
62. *J. communis* L., Aromatik, Estetik, Herdemyeşil
63. *J. oxycedrus* L., Aromatik, Estetik, Herdemyeşil

17. CYPERACEAE

64. *Carex tristis* M. Bieb., Estetik

18. CUSCUTACEAE
65. *Cuscuta kurdica* Engelmann.,Estetik
19. DIPSACACEAE
66. *Cephalaria amana* Rech., Estetik
67. *Dipsacus fullonum* L., Estetik
(Bu türler CAPRIFOLIACEAE familyasına aktarıldı.)

20. ELAEAGNACEAE
68. *Elaeagnus angustifolia* L., Aromatik, Estetik

21. EPHEDRACEAE
69. *Ephedra major* Host , Estetik, Herdemyeşil

22. EQUISETACEAE
70. *Equisetum ramosissimum* Desf., Estetik, Herdemyeşil

23. EUPHORBIACEAE
71. *Euphorbia szovitsii* Fisch&Mey, Estetik

24. FABACEAE
72. *Astragalus Compactus* Lam., Endemik, Estetik
73. *A. vexillaris* Boiss., Endemik, Estetik
74. *A.aureus* Willd., Estetik
75. *A.pinetorum* Boiss., Estetik
76. *A.microcephalus* Willd.
77. *A.kurdicus* Boiss., Estetik
78. *Astragalus lagopoides* Lam., Estetik
79. *A.macrocephalus* Willd., Estetik
80. *Colutea cilicica* Boiss., Estetik
81. *Coronilla varia* L., Estetik
82. *Glycyrrhiza glabra* L., Estetik
83. *Latyrus pratensis* L., Estetik
84. *Lotus corniculatus* L., Estetik
85. *Medicago sativa* L., Estetik
86. *Melilotus officinalis* (L.) Desv., Estetik
87. *Onobrychis cornuta* (L.) Desv., Estetik
88. *O. montana* D.C., Estetik
89. *O. viciifolia* Scop., Estetik
90. *Sophora alopecuroides* L., Estetik
91. *Trifolium repens* L., Estetik
92. *T. pratense* L., Estetik
93. *Trigonella monantha* C.A.Meyer, Estetik
94. *Vicia cracca* L., Estetik
95. *V. sativa* L., Estetik

25. FAGACEAE
96. *Quercus petraea* Menitsky.,Endemik takson, Estetik

26. FUMARIACEAE
97. *Fumaria microcarpa* Boiss.,Estetik

27. GERANIACEAE
98. *Erodium absinthoides* Wild., Estetik

28. HYPERICACEAE
99. *Hypericum perforatum* L., Estetik

29. IRIDACEAE
100. *Crocus pallasii* Goldb., Estetik
101. *Gladiolus atroviolaceus* Boiss., Estetik
102. *Iris caucasica* Hoffm.., Estetik

30. JUGLANDACEAE
103. *Juglans regia* L. Aromatik, Estetik

31. JUNCACEAE
104. *Juncus inflexus* L., Estetik

32. LAMIACEAE
105. *Acinos rotundifolius Pers.*, Aromatik, Estetik
106. *Ajuga chamaepitys* Schreber., Aromatik, Estetik
107. *Ballota. nigra* L. subsp. *nigra* , Aromatik, Estetik
108. *Lallementia iberica.* Fisch, et Mey., Aromatik, Estetik
109. *Lamium amplexicaule* L., Aromatik, Estetik
110. *L. garganicum* L.., Aromatik, Estetik
111. *L. purpureum* L., Aromatik, Estetik
112. *Stachys lavandulifolia* L.,Aromatik, Estetik
113. *Leonurus. glaucescens* Bunge., Aromatik, Estetik
114. *Marrubium cordatum* Nab., Aromatik, Estetik
115. *Mentha longifolia* (L.) Hudson., Aromatik, Estetik
116. *Mentha arvensis* L., Aromatik, Estetik
117. *M. pulegium* L., Aromatik, Estetik
118. *M. spicata* L., Aromatik, Estetik
119. *Nepata fissa* C.A. Meyer., Aromatik, Estetik
120. *N. nuda* L. subsp. *albiflora* Gams., Aromatik, Estetik
121. *N. transcaucasica* Grossh., Aromatik, Estetik
122. *Phlomis armeniaca* Willd. Endemik, Aromatik, Estetik
123. *P. tuberosa* L. Aromatik, Estetik
124. *Salvia aethiopis* L., Aromatik, Estetik
125. *S. brachyantha* (Bordz) Pobed., Aromatik, Estetik
126. *S. frigida* Boiss., Aromatik, Estetik
127. S. *kronenburgii* Rech. Endemik, Aromatik, Estetik
128. *S. limbata* C.A. Meyer., Aromatik, Estetik
129. *S. multicaulis* Vahl., Aromatik, Estetik
130. *S. nemorosa* L., Aromatik, Estetik
131. *S. pachystachys* Trautv., Aromatik, Estetik
132. *S. sclarea* L., Aromatik, Estetik
133. *S. staminea* Aucher ex Bentham., Aromatik, Estetik
134. *S. suffruticosa* Bentham., Aromatik, Estetik
135. *S. trichoclada* Bent., Aromatik, Estetik

136.*S. verticillata* L., Aromatik, Estetik
137.*S. virgata* Jacq., Aromatik, Estetik
138.*Scutelleria. orientilas* L.., Aromatik, Estetik
139.*Stachys. annua* L. ., Aromatik, Estetik
140.*S. cretica* L., Aromatik, Estetik
141.*S. lavandulifolia* Vahl. , Aromatik, Estetik
142.*Teuricum chamaedrys* L.., Aromatik, Estetik
143.T. polium L., Aromatik, Estetik
144.*Thymus fallax* Fisch.et Mey., Aromatik, Estetik
145.Thymus *fedtschenkoi* Ronniger , Aromatik, Estetik
146.*T. migricus* Klokov et Shost. Aromatik, Estetik
147.*T. transcaucasicus* Ronnger., Aromatik, Estetik
148.Ziziphora. capitata L., Aromatik, Estetik
149.*Z. persica* Bunge., Aromatik, Estetik
150.*Z. tenuior* L., Aromatik, Estetik

33. LILIACEAE
151.Allium akaka S.Gmelın., Aromatik,Estetik (Allium cinsi AMARYLLIDACEAE familyasına aktarıldı.)
152.*Bellevalia paradoxa* Woronow., Estetik (ASPARAGACEAE familyasına aktarıldı.)
153.*Fritillaria armena* Boiss., Endemik, Estetik
154.*F. minuta* Boiss., Estetik
155.*Gagea villosa* Bieb.,Estetik
156.*Muscari comosum* L., Aromatik, Estetik (ASPARAGACEAE familyasına aktarıldı.)
157.*M. neglectum* L., Aromatik, Estetik
158.*M. tenuiflorum* Tausch.., Estetik
159.*Ornitholalum narbonense* L., Estetik (ASPARAGACEAE familyasına aktarıldı.)
160.*Puschkinia scilloides* Adams., Estetik (ASPARAGACEAE familyasına aktarıldı.)
161.*Tulipa armena* Boiss., Estetik

34. LINACEAE
162.*Linum mucronatum* Bertol, Estetik

35. MALVACEAE
163.*Alcea calvertii* Boiss., Estetik
164.*Malva neglecta* Wallr., Estetik

36. ORCHIDACEAE
165.*Dactylorhiza osmanica* Soo., Endemik, Estetik

37. PAPAVERACEAE
166.*Papaver orientale* L., Estetik
167.*Glacium leiocarpum* Boiss., Estetik

38. PLANTAGINACEAE
168.*Plantago major* L., Estetik
169.*P. laceolata* L. ., Estetik
170.*Veronica anagallis-aquatica* L., Estetik
171.*V. anagalloides* Guss., Estetik
172.*V. persica* Poiret, Estetik
173.*V. heureka* M.A.Fisch., Estetik
174.V. orientalis Mill. ssp. *orientalis*., Estetik
175.*V. orientalis* Mill ssp. *carduchorum* D.,Endemik, Estetik

39. PLUMBAGINACEAE
176.*Acantholimon acerosum* Boiss., Estetik

40. POACEAE
177.*Bromus tomentellus* Boiss., Estetik
178.*Festuca airoides* Lam., Estetik
179.*Phragmites australis* Trin.,Estetik
180.*Stipa ehrenbergiaba* Trin&Rupr.,Estetik

36. POLYGONACEAE
181.*Rheum ribes* L., Estetik
182.*Rumex acutatus* L., Estetik

41. RANUNCULACEAE
183.*Adonis aestivalis* L., Estetik
184.*Consolida orientalis* Schröd., Endemik
185.*Delphinium carduchorum* Davis, Endemik, Estetik
186.*Ranunculus arvensis* L., Estetik
187.*R. kochii* Ledeb, Estetik
188.*R. polyanthemos* L., Estetik
189.*R. poluninii* Davis, Endemik, Estetik

42. RHAMNACEAE
190.*Frangula alnus* Miller, Estetik
191.*Rhamnus catharticus* L., Estetik

43. ROSACEAE
192.*Cotoneaster nummularia* Fısch&Mey., Estetik
193.*Potentilla recta* L., Estetik
194.*Rosa foetida* J Hermm ., Aromatik,Estetik
195.Rubus canescens D.C., Estetik
196.R. pimpinellifolia L., Aromatik, Estetik
197.*Sorbus umbellata* (Desf.)Fritsch., Estetik

44. RUBIACEAE
198.*Rubia tinctorum* L., Estetik

45. SALICACEAE
199.*Salix caprea* L.,, Estetik
200.*S. alba* L., Estetik
201.*Populus tremula* L., Estetik

46. SCROPHULARIACEAE
202.*Pedicularis comosa* L. var. *sibthorpii*, Estetik
203.*Linaria kurdica* Boiss.& Hohens, Estetik
204.*Lagotis stolonifera* Maxim, Estetik

47. SOLANACEAE
205.*Hyoscyamus niger* L.,Estetik
206.H. reticulatus L.,Estetik

207.*Solanum dulcamara* L.,Estetik

48. TYMELAEACEAE
208.*Daphne oleoides* Sch.,Aromatik,Estetik,Herdemyeşil

49. ULMACEAE
209.*Ulmus minor* Miller, Estetik

50. VIOLACEAE
210.*Viola odorata* L., Estetik
211.*V. arvensis* Murray, Estetik

Van Gölü havzası olarak seçtiğimiz araştırma bölgemizden topladığımız bitki numunelerinin değerlendirilmeleri sonucunda tür zenginliği bakımından familyalar Türkiye'nin aromatik bitkilerinin verildiği familyalar tablosu ile karşılaştırılmıştır (Baytop, 1984,1991). Tablodan da görüldüğü gibi, en fazla türe sahip ilk beş familya bakımından araştırma alanımız Türkiye geneli için benzerlik göstermektedir. Bundan anlaşılacağı üzere; bölge Türkiye geneli için şimdilik uyum içinde oransal ve sıralama olarak benzerlik göstermiştir. Zamanla tahribatla bu oranlar sapma göstermesi muhtemeldir.

Bu çalışma sonucunda teşhis edilen 600 bitki örneklerinin değerlendirilmesi sonucunda; 50 familyaya ait 211 tür belirlenmiştir. Teşhis edilen bitkilerin: 77 adet aromatik, 7 adet herdemyeşil, 211 adedide estetik süs bitkisi olarak belirlenmiştir. Endemizm sayısı ve oranı yönünden bu havza zengin olmasına karşın; aromatik bitki olarak topladığımız ve teşhis ettiğimiz bitkilerden 211 tür içinde endemiklerin sayısı 17ve oranı %11'dir. Ayrıca, bu çalışmada 21 tür hakkında ilk kez aromatik yönünden bilgi verilmesi nedeniyle de ayrıca önem arzetmektedir. Bunlar sırasıyla, *Achillea tenuifolia* Lam, *A. wilhelmsi* C.Koch., *Acinos rotundifolius* Pers., *Lallemantia iberica* (Bieb.), Fisch et Mey.,*Lamium amplexicaule* L., *L. garganicum* L., *Marrubium cordatum* Nab., *Nepeta fissa* C.A.Meyer., *Pimpinella corymboza* Borss., *Salvia brachyantha* (Bordz) Pobed., *S. frigida* Boiss.,*S. kronenburgii* Rech., *S. limbata* C.A. Meyer., *S. nentorosa* L., *S. staminea* Montbret et Aucher ex Bentham., *S. suffruticosa* Montbret Aucher ex Bentham., *S. verticillata* L.,. *Stachys cretica* L., *Ziziphora persica* Bunge'dir (Tablo 1).

Bu araştırmada tespit edilen taksonlar üzerinde peyzaj, süs, rekreasyon, biyokimyasal araştırmalar yapılarak değerlendirilmeleri ülkemiz ekonomisi açısından önem arz etmektedir ve araştırmalar için temel oluşturacaktır.

4. SONUÇ

Tablo 1. Van Gölü havzasında aromatik bitkilerin beş familyasının tür sayısı ve yüzde oranları.

FAMİLYALAR	TÜR SAYISI	HAVZA %	TÜRKİYE %
LAMIACEAE	46	61	40
ASTERACEAE	12	17	12
APIACEAE	4	7	10
LILIACEAE	3	3	7
ROSACEAE	2	3	4

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Science Teachers' Mentoring Roles for Parents from the Parents' Perspective

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Abstract: In this study was to determine the opinions of parents about the mentoring process of science teachers to parents. In order to achieve this aim, a descriptive survey model, one of the qualitative research designs, was used within the scope of the study. The sample of this study consisted of 120 parents whose children were enrolled in public or private schools affiliated with the Ministry of National Education during the 2022–2023 academic year, in both central and district areas of a city in western Turkey. This qualitative research aimed to explore parents' perspectives on the mentoring roles of science teachers directed toward them. Data were collected through an interview form administered to the participants. The findings indicated that parents believed they should be mentored by science teachers. Furthermore, they thought that such mentoring would have a positive impact on students' academic and personal development. It is recommended that science teachers receive in-service training and regularly engage in mentoring activities with parents to enhance the effectiveness of their mentoring roles.

Velilerin Gözünden Fen Bilimleri Öğretmenlerinin Velilere Yönelik Mentorluk Rolleri

Anahtar Kelimeler:
Fen bilimleri öğretmeni,
Mentorluk,
Veli

Özet: Bu çalışmada velilerin, fen bilimleri öğretmenlerinin velilere yapmış oldukları mentorluk süreci ile ilgili görüşlerini belirlemek amaçlanmıştır. Bu amaca ulaşmak için çalışma kapsamında nitel araştırma desenlerinden betimsel tarama modeli kullanılmıştır. Çalışmanın örneklemi, Türkiye'nin batısındaki bir şehrin merkez ve ilçelerinde 2022-2023 eğitim-öğretim yılında MEB'e bağlı özel veya kamu kuruluşunda öğrenim gören 120 öğrencinin velisinden oluşturmaktadır. Çalışmanın verileri katılımcılara uygulanan görüş formu yardımıyla toplanmıştır. Çalışmanın sonucunda velilerin kendilerine mentorluk yapılması gerektiğini düşündükleri belirlenmiştir. Ayrıca, velilere mentorluk yapılmasının öğrencilerin akademik ve kişisel gelişimi üzerinde olumlu etki yaratacağını düşündükleri sonucuna da varılmıştır. Fen bilimleri öğretmenlerinin daha verimli mentorluk yapabilmeleri için kendilerine hizmet içi eğitimlerin verilmesi ve veliler ile düzenli aralıklarla mentorluk faaliyetleri gerçekleştirmeleri önerilmektedir.

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1.INTRODUCTION

Throughout history, people have always needed a wiser and more experienced mind than their own. This wise mind sometimes represents an older person or someone who can guide them in terms of education, talent, and skills. Mentoring is the process of guiding individuals by sharing their knowledge and experience, and it is not only a short-term process but also a process that covers the entire lifespan (Paçalı, 2019; Efe, 2019). Within this process, mentors may take on various roles and appear in different contexts (Miller, 2005). Initially, this role is assumed by the mother and father from birth (Hatipoğlu & Kavas, 2016). As the individual begins school, teachers and peers also begin to share in this role previously held by the family (Gülşen Çelik, 2010). Over time, as individuals move toward different paths and directions in life, they may feel the need to choose a new mentor. In this case, even if the mentor is chosen from different individuals, their role is always the same and is to provide the guidance and support that the individual needs (Avcı, 2019).

Teachers are undoubtedly the ones who assume the role of mentor in the academic process of the individual. In addition to ensuring the effectiveness and continuity of the process, teachers also provide guidance to the society in which they live. While preparing their students for life in pedagogical, academic, and social terms, they also support parents, who are indirectly involved in this process and who sometimes feel helpless or inadequate, with their knowledge, skills, and experience (Avcı, 2019). By assuming this mentoring role, teachers enable parents to take a more active part in the educational process and contribute to their children's academic success. In addition, thanks to the positive communication between parents and teachers, they can get to know their children better, recognize their needs, and deal more closely with their needs (Hatipoğlu & Kavas, 2016). Additionally, teachers can enhance the overall quality of the educational process by properly managing student-parent interactions (Dinler & Hacıfazlıoğlu, 2020). Similarly, Avcı (2019) states in his study that since parents are an important part of the education process, science teachers should mentor them with their knowledge, skills, attitudes, behaviors, and experiences. He also states that science teachers should guide the education and training process with mentoring practices. Effective and accurate guidance stands out as a determining factor in increasing the efficiency and quality of the educational process. When teachers effectively structure and implement communication between students and parents, it fosters the development of qualified and productive individuals, thereby contributing significantly to the future of society (Canlı, 2023). The mentoring offered by science teachers to parents contributes to the development of healthy relationships between students, parents, and the school and supports the positive progress of the educational process. Teachers should always adopt a constructive and solution-oriented approach to leave a lasting, positive impact on both students and parents (Avcı, 2019).

Within the scope of the study, it was aimed to examine parents' views on the mentoring roles of science teachers for student parents. Although there are numerous studies in the literature on the concept of mentoring, no research has been found that specifically addresses science teachers' mentoring practices directed at parents. The research has an important place in terms of trying to reveal the mentoring levels of science teachers in line with the views of parents. In addition, considering the benefits of mentoring, it is thought that it is important to reveal the mentoring of science teachers to parents from the perspective of parents. Through this study, science teachers can have the opportunity to examine the views of parents about the mentoring done by their colleagues. In addition, science teachers can also have the opportunity to evaluate themselves by considering these views. In this respect, it is thought that the study will contribute to the literature, raise awareness about mentoring for science teachers, help parents understand mentoring better, and provide a basis for future research. In this context, the problem statement of the study was determined as "What are the views of parents on the mentoring role of science teachers for parents?". In addition, hypotheses are given below in line with the purpose of the study.

- Parents think that science teachers are unable to mentor them.
- Parents think that science teachers should only mentor students.

2. MATERİALS AND METHODS

2.1. Research Design

In order to achieve the aim of the study, the opinions of the parents were collected with a semi-structured interview form developed by Avcı (2019). In this context, the descriptive survey model, one of the qualitative research approaches, was used in the study. In this model, the main purpose is to present an ongoing situation or a past situation as it is (Karasar, 2015). Descriptive studies are studies aimed at understanding the current status of events, objects, institutions, and various fields. Büyüköztürk (2005) defines these studies as describing a given situation as completely and carefully as possible.

2.2. Participants

The data of the study were collected from 120 parents of students in the center and districts of a city in western Turkey during the 2022-2023 academic year. The study employed the simple random sampling method, which is one of the probability sampling techniques. Simple random sampling is generally preferred to ensure impartiality in the selection of the sample and to increase the likelihood that the sample represents the population (Kaptanoğlu, 2013). In this method, the participants to be included in the sample are randomly selected, which makes the results more generalizable and reliable (Çepni, 2010).

2.3. Data Collection

Within the scope of the study, it was planned to use the open-ended interview form developed by Avcı (2019) to determine parents' views on the mentoring role of science teachers towards parents (Form title: Questionnaire on the Mentoring Role of Classroom Teachers on Parents). Before this open-ended interview form was applied to the sample group, the questions in the form were reorganized to suit the purpose of the study.

Question 1 on the original form: Do you think that classroom teachers act as mentors to you?

Question 1 in the revised form: Do you think science teachers act as mentors to you?

The revised form was reviewed in collaboration with three science educators and one linguist, all specialists in their respective fields, and was finalized accordingly. In this context, the interview form, which originally consisted of 19 questions, was reduced to 15 questions by removing the 7th, 8th, 11th, and 18th questions. Open-ended questions enable participants to respond freely and in detail and are generally referred to as unstructured questions (Bahar et al., 2010). These types of questions allow the respondent to freely express their views, thoughts, and experiences, thus deeper and more qualified data can be obtained (Büyüköztürk, 2005).

2.4. Data Collection Process

Within the scope of the study, the form developed by Avcı (2019) was designed for parents of students taught by science teachers and was administered individually over a period of four weeks during the spring semester of 2023. During the implementation process, participants completed the form either online or face-to-face, depending on their preference.

2.5. Data Analysis

The descriptive statistics method was used to analyze the data collected within the scope of the study. This method helps researchers gain a general perspective on different phenomena and events they aim to investigate and allows data to be summarized in terms of basic trends, distributions, and averages (Büyüköztürk et al., 2008). The data collected in the study were presented in tables using frequencies and percentages. The answers given by the participants were also analyzed by different researchers, and reliability was calculated according to the Miles and Huberman (1994) formula. For example, the reliability values were calculated as 93% for the parent-coded V1, 90% for the parent-coded V2, and 87% for the parent-coded V3. According to Miles and Huberman (1994), reliability calculations greater than 70 % indicate that the analysis is reliable. In this context, it can be stated that the analysis of the data obtained from semi-structured interviews is reliable.

2.6. Research Ethics

This research was carried out with the approval of the Ethics Committee of the Kafkas University Social and Human Sciences Scientific Research and Publication Ethics Board, dated April 21, 2022. The research was also conducted following the 'Scientific Research and Publication Ethics' guidelines of Higher Education Institutions.

3. RESULTS AND DISCUSSION

The form prepared for the problem sentence "What are the opinions of parents about the mentoring role of science teachers on parents?" was applied to the participants, and the data obtained were analyzed by experts. The findings obtained within the scope of this analysis are given below in order.

3.1. Findings related to the first question in the parent interview form

The themes and codes obtained from the analysis of the parents' answers to the question "Do you think science teachers act as mentors to you?" are presented in Table 1.

Table 1. The themes and codes obtained from the answers to the first question in the parent interview form

Theme	Code	f	%
Thinking	Education issues	36	30
	About LGS	18	15
	About the developmental process	12	10
I don't think so	Not being able to meet with the teacher	24	20
	Only academic information	22	18,3
Partially	Academic subjects	8	6,7
Total		**120**	**100**

When Table 1 was examined, it was seen that 55% of the parents answered the question "Do you think that science teachers mentor you?" as "thinking", 38.3% as "ı don't think so", and 6.7% as "partially". In addition, it was determined that 30% of the parents who answered the question as "thinking" stated that science teachers mentored them on "educational issues", 15% on "about LGS", and 10% on "about the developmental process". Sample parent answers in which these themes and codes were identified are presented below.

A sample statement from participant V6 (parent 6) indicating that science teachers mentor parents on “educational issues”:

"On every subject related to the student's education.”

A sample statement from participant V25, who indicated that science teachers provide mentoring to parents "about LGS":

"Especially because the student is in 8th grade, the teacher helps with LGS-related subjects."

It was determined that 20% of the parents who answered with "ı don't think so" to the relevant question in the interview form believed that science teachers could not mentor them due to "not being able to meet with the teacher" and 18.3% believed that teachers could not mentor them because they provided "only academic information" to parents.

A sample statement from participant V36, who indicated that science teachers do not provide mentoring to parents due to "not being able to meet with the teacher":

"The teacher works very hard. We only meet when there are problems."

It was determined that parents who answered "partially" to the question "Do you think that science teachers mentor you?" believed that science teachers partially provide mentoring in "academic subjects". Below is an example answer from the parents to the interview question where this theme and code were identified.

A sample statement from participant V35, who indicated that science teachers have the responsibility to mentor parents on "academic issues":

"She only provides information about the student's academic progress. For other matters, she advises us to speak with the guidance counselor."

3.2. Findings related to question 2 in the parent interview form

The themes and codes obtained from the analysis of the parents' answers to the question "Do you think science teachers have a mentoring responsibility towards parents?" are presented in Table 2.

Table 2. The themes and codes obtained from the answers to question 2 in the parent interview form

Theme	Code	f	%
Yes	There should be teacher-parent cooperation	26	21,7
	Education is a whole.	22	18,3
	Academic information	17	14,2
No	The age of technology	24	20
	The role of the guidance counselor	12	10
	Excessive workload	7	5,8
Partially	Academic subjects	8	6,7
	The development of the student	4	3,3
Total		**120**	**100**

When Table 2 was examined, it was seen that 54.2% of the parents answered the question "Do you think science teachers have a mentoring responsibility towards parents?" as "yes", 35.8% as "no", and 10% as "partially". Furthermore, it was determined that 21.7% of the parents who answered the question as "yes" stated that science teachers mentored them on "there should be teacher-parent collaboration", 18.3% on "education is a whole", and 14.2% on "academic information". Sample parent answers in which these themes and codes were identified are presented below.

A sample statement from participant V6, who indicated that science teachers have a responsibility to mentor parents, based on the idea that "there should be teacher-parent cooperation":

"The teacher should always cooperate with the parents."

A sample statement from participant V1, who indicated that science teachers have a responsibility to mentor parents, based on the idea that "education is a whole":

"Education should support the students' development in every aspect; therefore, it is a whole."

It was determined that 20% of the parents who answered with "no" to the relevant question in the interview form believed that science teachers did not mentor them because we are in the "the age of technology", 10% believed that it was the "the role of the guidance counselor" and 5.8% believed that it required "excessive workload". Below is an example answer from the parents to the interview question where these themes and codes were identified.

A sample statement from participant V38, who indicated that science teachers do not have a responsibility to mentor parents, based on the idea that "technology age":

"We live in the age of technology and can access the information we need whenever we want."

It was determined that 6.7% of the parents who answered "partially" to the second question in the interview form believed that science teachers partially mentored them in "academic subjects", while 3.3% believed the mentoring was related to "the development of the student".

3.3. Findings related to question 3 in the parent interview form

The themes and codes obtained from the analysis of the parents' answers to the question "Do you find science teachers' knowledge, skills, and experience sufficient to fulfill this role?" are presented in Table 3.

Table 3. The themes and codes obtained from the answers to question 3 in the parent interview form

Theme	Code	f	%
Yes	Subject matter expert	50	41,7
	Very interested	20	16,7
	Psychological support	14	11,7
	About development	10	8,3
No	Disinterested	19	15,8
	Intense work schedule	7	5,8
Total		**120**	**100**

When Table 3 is examined, it is seen that 78.4% of the parents responded with "yes" and 21.6% answered "no" to the question, "Do you find science teachers' knowledge, skills, and experience sufficient to fulfill this role?". In addition, it was determined that 41.7% of the parents who responded with "yes" to the question stated that they considered science teachers adequate to undertake the mentoring role because they were "subject matter expert", 16.7% because they were "very interested", 11.7% because they provided "psychological support" and 8.3% because they helped "about development". Below is an example answer from the parents to the interview question where these themes and codes were identified.

A sample statement from participant V6, in which the code "subject matter expert" was identified, indicating that the science teacher's knowledge and skills were sufficient in the mentoring process:

"A teacher who is proficient in their field and continuously works on self-improvement."

Among the parents who responded with "no" to the related question in the interview form, 15.8% stated that science teachers were not sufficient in the mentoring process due to being "disinterested" and 5.8% due to being "an intense work schedule". Below is an example answer from the parents to the interview question where these themes and codes were identified.

A sample statement from participant V26, in which the code "intense work schedule" was identified, indicating that the science teacher's knowledge and skills were insufficient in the mentoring process:

"The teacher has an excessive workload and a high number of classes, which is why."

3.4. Findings related to question 4 in the parent interview form

The themes and codes obtained from the analysis of the parents' answers to the question "What additional characteristics should a science teacher with sufficient professional knowledge and skills possess to mentor you?" are presented in Table 4.

Table 4. The themes and codes obtained from the answers to question 4 in the parent interview form

Theme	Code	f	%
Education	Communication skills	21	15,3
	Content Knowledge	19	13,9
	Professional experience	9	6,6
	Mentor	5	3,6
	Psychological	3	2,2
Personality	Empathy	13	9,5
	Interest	7	5,1
	Self-improvement	6	4,4
	Mentor	5	3,6
	Fair	4	2,9
	Patient	4	2,9
	Innovator	3	2,2
	Helpful	1	0,7
	Funny	1	0,7
	Self-confident	1	0,7
	Skill	1	0,7
Adequate	Sufficient	34	24,8
Total		**137**	**100**

When Table 4 is examined, it is seen that 41.6% of the parents responded with “education,” 33.4% “personality,” and 24.8% “adequate” to the question, “What qualities, other than the knowledge and skills of a sufficiently qualified science teacher, do they need to have to mentor you?”. Additionally, 15.3% of the parents who answered with 'education' stated that science teachers should have 'communication skills' and 13.9% emphasized the importance of having 'content knowledge'. Below is an example answer from the parents to the interview question where these themes and codes were identified.

A sample statement from participant V89, who indicated that science teachers should have "communication skills" in addition to the characteristics they should have to mentor parents:

"They should communicate the topic in a way that the listener can understand. They must establish effective communication."

It was determined that 9.5% of the parents who responded with the related question in the interview form "personality" thought that science teachers should have a sufficient level of "empathy", 5.1% "interest", and 4.4% "self-development" abilities in addition to their knowledge and skills. Sample parent answers in which these themes and codes were identified are presented below.

A sample statement from participant V46, who indicated that science teachers should possess the quality of "interest" in addition to the necessary characteristics to mentor parents:

"They should show interest and kindness towards the student."

A sample statement from participant V63, who indicated that science teachers should possess the quality of "self-improvement " in addition to the necessary characteristics to mentor parents:

"It is necessary for them to read books, follow current events, and attend various courses and seminars."

3.5. Findings related to question 5 in the parent interview form

Within the scope of the study, the themes and codes obtained from the analysis of the parents' answers to the questions "Do you think that science teachers should take care of your problems? In which subjects does the science teacher mentor you?" are presented in Table 5.

Table 5. The themes and codes obtained from the answers to question 5 in the parent interview form

Theme	Code	f	%
Thinking	Promoting a love of science	24	20,0
	General topics	8	6,7
	Student development	3	2,5
	Health	2	1,7
I don't think so	Excessive workload	35	29,2
	Not in the job description	11	9,2
I think partially	According to the topic	37	30,8
Total		**120**	**100**

When Table 5 is examined, it is seen that 30.9% of the parents responded with "thinking", 38.4% "I don't think so" and 30.8% "I think so partially" to the question "Do you think that science teachers should take care of your problems? In which subjects does the science teacher mentor you?". In addition, it was determined that 20% of the parents who answered the related question as "thinking" stated that science teachers should mentor them by using the expressions "promoting a love of science" and 6.7% "general topics". Sample parent answers in which these themes and codes were identified are presented below.

A sample statement from Participant V7, who indicated that the science teacher provided mentorship in the about "promoting a love of science":

"In promoting a love of science and encouraging research skills."

A sample statement from Participant V73, who indicated that the science teacher provided mentorship on "general topics":

"They show interest. They provide mentorship in student-parent communication, academic achievement, and communication between school and home."

It was determined that 29.2% of the parents who answered “ı don't think so” to question 5 in the form believed that science teachers do not attend to parents' problems due to "excessive workload", and 9.2% due to the perception that it is "not in the job description".

A sample statement from Participant V97, who indicated that the science teacher did not provide mentorship due to "excessive workload":

"When we go to school, the teacher is generally busy dealing with student issues and cannot pay much attention to us."

It was determined that 5.4% of the parents who answered "ı think partially" to the relevant question in the interview form believed that science teachers partially attend to their problems, "according to the topic".

A sample statement from Participant V61, from which the code "according to the topic" was identified based on their response to the relevant question:

"They only get involved when there is a problem related to the student's academics or behavior."

3.6. Findings related to question 6 in the parent interview form

The themes and codes obtained from the analysis of the parents' answers to the questions "In which subjects do you expect help and support from the science teacher? Does the science teacher meet your expectations in this regard?" are presented in Table 6.

Table 6. The themes and codes obtained from the answers to question 6 in the parent interview form

Theme	**Code**	**f**	**%**
Student-related issues	Academic	37	30,8
	Projects	8	6,7
	Developmental	5	4,2
	Health	2	1,7
Not expecting support	Self-sufficient	12	37,5
	Supported by a coach	11	10,0
	Teacher in the family	12	9,2
Total		**120**	**100**

When Table 6 is examined, it is seen that 43.4% of the parents responded to the question "In which subjects do you expect help and support from the science teacher?" with "student-related issues," while 56.7% stated that they "do not expect support". In addition, among the parents who answered the question with "student-related issues," 30.8% requested support from science teachers on "academic" matters, and 6.7% on "projects."

A sample statement from participant V47 in which they indicated that they expected support from their science teacher regarding "projects":

"We are seeking support in raising children who are interested in science and in learning how to properly complete project assignments."

Among the parents who answered "not expecting support" to the 6th question in the interview form, 37.5% indicated that they are self-sufficient, 10% reported receiving coaching support, and 9.2% stated that there is a teacher in the family, thus expressing that they do not expect help or support from the science teachers.

A sample statement by participant V87 indicates that they do not expect support from science teachers due to the belief that "there is a teacher in the family":

"I do not expect help or support. There is a teacher in the family."

3.7. Findings related to question 7 in the parent interview form

Within the scope of the study, the themes and codes obtained from the analysis of the parents' answers to the questions "What problems do you encounter during the mentoring process? What are the positive or negative situations you encounter?" are presented in Table 7.

Table 7. The themes and codes obtained from the answers to question 7 in the parent interview form

Theme	**Code**	**f**	**%**
No problems encountered	No problems encountered	98	81,6
Problems encountered	Experience	2	1,6
	Time	5	4,6
	Psychology	1	0,8
	Education	10	8,2
	Contact	4	3,2
Total		**120**	**100**

When Table 7 is examined, it is seen that 81.6% of the parents' responses to the question "What problems do you encounter during the mentoring process?" reflect the theme of "no problems encountered", while 18.4% reflect the theme of "problems encountered". In addition, it was determined that among the parents associated with the theme of "problems encountered", 8.2% used words such as "education", 4.6% referred to "time", and 3.2% mentioned "communication" to express the difficulties they experienced during the mentoring process. Sample parent responses in which these themes and codes were identified are presented below.

A sample statement from participant V70, from which the code "no problems encountered" was identified based on their response to the relevant question:

"I did not encounter any problems. I was able to meet with the teacher when I went to the school."

A sample statement from participant V93, from which the code "time" was identified based on their response to the relevant question:

"Time issue. The teacher is often unavailable due to time constraints and a heavy workload."

3.8. Findings related to question 8 in the parent interview form

The themes and codes obtained from the analysis of the parents' answers to the questions "Where and how often do you meet with the science teacher? Who determines the meeting times?" are presented in Table 8.

Table 8. The themes and codes obtained from the answers to question 8 in the parent interview form

Theme	Code	f	%
School administration	At a parent-teacher meeting	37	30,8
	When the school administration calls	35	29,2
Teacher	When the teacher calls	20	16,7
	For academic status	9	7,5
Teachers and parents together	Once a month	12	10,0
	Whenever there is an opportunity	7	5,8
Total		**120**	**100**

When Table 8 is examined, it is seen that 60% of the parents' responses to the question “Where and how often do you meet with the science teacher? Who determines the meeting times?” reflect the themes of “school administration”, 24.2% reflect the theme of “teacher”, and 15.8% reflect the theme of “teacher and parent together”. Additionally, it was determined that among the parents whose responses reflected the “school administration” theme, 30.8% used the phrase “at a parent-teacher meeting” while 29.2% stated “when the school administration calls”. Among the parents whose responses reflected the “teacher” theme, 16.7% used the phrase “when the teacher calls,” and 7.5% stated “for academic reasons”. Moreover, among those whose answers reflected the theme of “teacher and parents together,” 10% used the expression “once a month” and 5.8% said “whenever there is an opportunity”. Sample parent responses in which these themes and codes were identified are presented below.

A sample statement from participant V93, from which the code “at the parent-teacher meeting” was identified based on their response to the relevant question:

"We meet at the school during the parent-teacher meetings."

A sample statement from participant V55, from which the code “when the teacher calls” was identified based on their response to the relevant question:

"The teacher calls and invites me to meet whenever there is a problem or something extra I need to know."

A sample statement from participant V76, from which the code "whenever there is an opportunity" was identified based on their response to the relevant question:

"I always try to go whenever the teacher is available."

3.9. Findings related to question 9 in the parent interview form

Within the scope of the study, the themes and codes obtained from the analysis of the parents' answers to the questions “Can the science teacher reach you easily?” and “Can you easily reach the science teacher?” are presented in Table 9.

Table 9. The themes and codes obtained from the answers to question 9 in the parent interview form

Theme	Code	f	%
Reachable	Contact information	80	66,7
	Whatsapp groups	34	28,3
Unreachable	Missing contact details	6	5,0
Total		**120**	**100**

When Table 9 is examined, it is seen that 95% of the parents’ responses to the questions "Can the science teacher reach you easily? Can you easily reach the science teacher?" reflect the theme of “reachable”, while 5% reflect the theme of “unreachable”. In addition, it was determined that among the parents associated with the theme of "reachable", 66.7% used expressions such as "contact information" and 28.3% referred to "WhatsApp groups" to indicate that they could easily communicate with the teacher. On the other hand, it was found that all of the parents who reflected the theme of "unreachable" used the expression "missing contact details" to explain their difficulty in reaching the science teacher.

A sample statement from participant V75 regarding the situation of being able to contact teachers, in which the code “contact information” was identified:

"They're just a phone call away; we can reach them easily."

A sample statement from participant V81 regarding the situation of being able to contact teachers, in which the code “missing contact details” was identified:

"We don’t have any of the teacher’s contact information. We don’t know the phone number, so I can’t reach them whenever I want."

3.10. Findings related to question 10 in the parent interview form

The themes and codes obtained from the analysis of the parents' answers to the question "Can you comfortably express your ideas and opinions to the science teacher?" are presented in Table 10.

Table 10. The themes and codes obtained from the answers to question 10 in the parent interview form

Theme	Code	f	%
I can say	For better education	85	70,8
	Because of their sincerity	16	13,3
I can't say it	We can't meet	12	10,0
	Because they are a subject teacher	3	2,5
I can partially say	Only on matters related to the student	4	3,3
Total		120	100

When Table 10 is examined, it is seen that 84.1% of the parents’ responses to the question “Can you comfortably express your ideas and opinions to the science teacher?” reflected the theme of “ı can say”, 12.5% “ı can't say it”, and 3.3% “I can partially say”. It was determined that among the parents associated with the theme of "ı can say", 70.8% used the expression "for better education" and 13.3% mentioned "because of their sincerity". In the responses of parents linked to the theme of "ı can't say it", 10% used the expression "we cannot meet," and 2.5% referred to "because they are a subject teacher". Furthermore, all parents identified with the theme of "ı can partially say" used the phrase "only on matters related to the student". Sample parent responses in which these themes and codes were identified are presented below.

A sample statement from participant V75 in response to the related question, in which the code "for better education" was identified:

"Of course, I say it for the student's academic success and development."

A sample statement from participant V96 in response to the related question, in which the code "because they are a subject teacher" was identified:

"I look at it differently because of their specialty."

A sample statement from participant V75 in response to the related question, in which the code "only on matters related to the student" was identified:

"I talk about matters concerning the student and enhancing their academic success."

3.11. Findings related to question 11 in the parent interview form

Within the scope of the study, the themes and codes obtained from the analysis of the parents' answers to the questions "Do you meet with the science teacher outside of school? If so, what is the purpose and content of these meetings?" are presented in Table 11.

Table 11. The themes and codes obtained from the answers to question 11 in the parent interview form

Theme	Code	f	%
I meet	For homework	8	6,7
	For academic matters	2	1,7
	Friendly (Chat)	1	0,8
I don't meet	I don't need.	70	58,3
	We meet at school	39	32,5
Total		**120**	**100**

When Table 11 is examined, it is seen that 9.2% of the parents' responses to the question "Do you meet with the science teacher outside of school? If so, what are the purpose and content of these meetings?" revealed the themes "ı meet" and 90.8% "I don't meet". Additionally, among the parents who stated "ı meet", 6.7% mentioned "for homework" as the reason for these meetings. Furthermore, of the parents who stated "ı don't meet", 58.3% said "ı don't need" and 32.5% said "we meet at school". Sample parent responses in which these themes and codes were identified are presented below.

A sample statement from participant V33, from which the code "for homework" was identified based on their response to the relevant question:

"I communicate with the teacher for homework."

A sample statement from participant V78, from which the code "we meet at school" was identified based on their response to the relevant question:

"We meet within the school boundaries. It's enough."

3.12. Findings related to question 12 in the parent interview form

The themes and codes obtained from the analysis of the parents' answers to the question "Would you prefer to meet with the science teacher within the formal boundaries of the school as a parent-teacher interaction, or in a more informal and friendly setting?" are presented in Table 12.

Table 12. The themes and codes obtained from the answers to question 12 in the parent interview form

Theme	Code	f	%
Within the boundaries of the school, within the official parent-teacher relationship	Should be formal	75	62,5
	Should be boundaries	15	12,5
	Within the institution and formal	3	2,5
In a less formal setting and a friendly manner	Friendly	16	13,3
	Sincere	11	9,2
Total		**120**	**100**

When Table 12 is examined, it is seen that 77.5% of the parents' responses to the related question revealed the theme "within the boundaries of the school, within the official parent-teacher relationship" and 22.5% reflected the theme "In a less formal setting and a friendly manner". Additionally, among the parents whose responses were categorized under the theme "parent-teacher formality within school boundaries", 62.5% used the expression "should be formal," and 12.5% used the expression "Should be boundaries". Furthermore, it was found that 13.3% of the parents in the "in a less formal setting and a friendly manner" theme used the expression "friendly" and 9.2% used "sincere" in their responses. Sample parent responses in which these themes and codes were identified are presented below.

A sample statement from participant V88, from which the code "should be formal" was identified based on their response to the relevant question:

"It should be within the boundaries of a formal parent-teacher relationship."

Sample statements from participant V38, from which the codes "friendly" and "sincere" were identified based on their responses to the relevant question:

"I think we should have a friendly relationship with the teacher."

"Rather than being formal, she is also a mother. She can be warmer and sincere. We're not doing a job interview."

3.13. Findings related to question 13 in the parent interview form

The themes and codes obtained from the analysis of the parents' answers to the question "Do you have any limitations in your meetings with the science teacher? If so, how and why?" The themes and codes obtained from the analysis of their answers to the questions are presented in Table 13.

Table 13. The themes and codes obtained from the answers to question 13 in the parent interview form

Theme	Code	f	%
There is	Time	18	15
	Boundaries	10	8,3
	Subject	2	1,7
None	Within the framework of respect	55	45,8
	For student development	35	29,2
Total		**120**	**100**

When Table 13 is examined, it is seen that 25% of the parents' responses to the question "Do you have any limitations in your meetings with the science teacher? If so, how and why?" revealed the theme of "there is" and 75% revealed the theme of "there isn't". In addition, among the parents for whom the theme "there is" was identified, 15% used the expression "time" and 8.3% used the expression "boundaries" in their responses. On the other hand, among the parents for whom the theme "there isn't" was identified, 45.8% used the expression "within the framework of respect" and 29.2% used the expression "for student development". Sample parent responses in which these themes and codes were identified are presented below.

A sample statement from participant V29, from which the code "time" was identified based on their response to the relevant question:

"Yes, there are limits, especially regarding time."

A sample statement from participant V38, from which the code "boundaries" was identified based on their response to the relevant question:

"I do have limits. There needs to be certain boundaries in communication between teachers and parents."

A sample statement from participant V79, from which the code "within the framework of respect" was identified based on their response to the relevant question:

"I think conversations and meetings should take place within the bounds of respect."

3.14. Findings related to question 14 in the parent interview form

The themes and codes obtained from the analysis of the answers to the questions "What is the purpose of your mentoring relationship with the science teacher? What effects do you expect from the science teacher as a result of this sharing?" are presented in Table 14.

When Table 14 is examined, it is seen that 88.3% of the parents' responses to the related question revealed the theme of "positive effects" and 11.7% revealed the theme of "no opinion". In addition, among the parents for whom the theme "positive effects" was identified, 17.5% used the expression "interest and ability", 16.7% "responsibility", 15.8% "communication skill", 13.3% "academic development", and 12.5% "sense of curiosity" in their responses. On the other hand, all parents identified with the theme of "no opinion" used the phrase "no opinion".

Table 14. The themes and codes obtained from the answers to question 14 in the parent interview form

Theme	Code	f	%
Positive effects	Interest and ability	21	17,5
	Responsibility	20	16,7
	Communication skill	19	15,8
	Academic development	16	13,3
	Sense of curiosity	15	12,5
	Social development	15	12,5
No opinion	No opinion	14	11,7
Total		**120**	**100**

A sample statement from participant V86, from which the code "sense of curiosity" was identified based on their response to the relevant question:

"It allows me to discover new things."

A sample statement from participant V48, from which the code "no opinion" was identified based on their response to the relevant question:

"I have no idea at all."

3.15. Findings related to question 15 in the parent interview form

The themes and codes obtained from the analysis of the parents' answers to the question "How do you think mentoring affects the parent-teacher relationship?" are presented in Table 15.

Table 15. The themes and codes obtained from the answers to question 15 in the parent interview form

Theme	Code	f	%
Positive	Responsibility	25	20,8
	Respect	19	15,8
	Empathy skill	14	11,7
	Provides comfort	11	9,2
	Provides guidance	18	15
	Bilateral relationship	7	5,8
Does not affect	Does not affect	16	13,3
No opinion	We don't communicate	10	8,3
Total		**120**	**100**

When Table 15 is examined, it is seen that 78.4% of the parents' responses to the related question were coded under the theme "positive," 13.3% under "does not affect," and 8.3% under "no opinion." In addition, among the parents identified with the "positive" theme, 20.8% used the expression "responsibility," 15.8% "respect," and 11.7% "empathy skill" in their responses. Furthermore, it was determined that all parents whose responses were coded under the "does not affect" theme used the expression "does not affect," and all parents under the "no opinion" theme used the expression "we don't communicate" in their responses.

4. CONCLUSION

When the data obtained within the scope of the study were analyzed, it was determined that the parents thought that science teachers particularly mentored them regarding students' academic development, the examination process (e.g., LGS), and educational issues, and that this led to positive developments in students. In addition, it was found that parents thought they were able to guide their children more effectively thanks to the mentoring support they received from teachers. It is anticipated that informing parents may contribute positively to teacher-parent-student communication, thereby enhancing the overall quality of education. Supporting this situation, the literature also emphasizes that teachers' mentoring roles constitute an important factor in improving student achievement (Anderson & Shannon, 1988). Similarly, Allen and Eby (2003) argue that effective mentoring offers a range of benefits for both mentors and mentees. Kocabaş and Yirci (2011) highlight that the benefits of mentoring for mentees include personal satisfaction, the ability to conduct research and think critically, the capacity to transfer knowledge on new topics, effective problem-solving skills, and increased self-awareness. In addition, within the scope of the study, it was revealed that parents expected science teachers to provide help and support in academic matters, and that these expectations were generally met by the relevant teachers. It was determined that parents believed the mentoring provided or to be provided by teachers would help resolve problems before they emerge or grow. The reason why parents and teachers communicate more on academic issues can be considered the constant renewal of science in the age of changing and developing technology, with the curriculum change.

The majority of parents stated that science teachers possessed the necessary knowledge and skills to act as mentors. They also indicated that teachers with strong subject knowledge, professional experience, and a commitment to self-improvement were likely to be more effective mentors. According to Holloway (2001), a mentor should be trustworthy, open-minded, kind, and capable of keeping confidences. Kalin et al. (2009) describe a mentor as a humble individual, Mertz (2004) defines the mentor as a guide and supporter, and Brockbank and McGill (2006) characterize a mentor as someone capable of demonstrating empathy. Developing teachers' mentoring skills can enhance both student achievement and parent satisfaction (Özdem Yılmaz et al., 2024).

Some parents stated that science teachers showed interest in their problems, while others indicated that, due to the heavy workload and lack of a clearly defined mentoring role in their job descriptions, teachers did not sufficiently address parental issues. In order for education to improve and reach the desired level, teachers and educational institutions need to involve families in cooperation with the school. In this way, it is believed that a positive parental attitude toward the school and desirable developmental outcomes in students may emerge. Among the qualities that parents expected from teachers in the mentoring process, personal competencies such as communication skills, empathy, attentiveness, and a commitment to self-improvement came to the forefront. This finding demonstrates that teaching as a profession requires not only academic expertise but also social and emotional competencies. Possessing these skills may enable teachers to fulfill their mentoring roles more effectively (Beigi Rizi et al., 2021). Within the scope of the study, it was also revealed that nearly all parents did not encounter any significant problems during the mentoring process, while only a few experienced difficulties related to time and communication. These challenges could potentially be mitigated by allocating dedicated time for teachers to engage in mentoring, free from other responsibilities. Limited communication between teachers and parents may hinder the effective implementation of mentoring roles. In the literature, the importance of open and continuous communication for effective mentoring is frequently emphasized (Ensher et al., 2003). Conway (2002) also emphasized in his study that communication between mentor and mentee is a critical component. Students who perceive that they are supported and monitored by both their families and teachers are more likely to demonstrate positive development.

Within the scope of the study, it was determined that meetings between science teachers and parents at school were mostly held with regard to a specific problem or need. In this way, they stated that the formality between teacher and parent was maintained and that communication was healthier. Boyle and Boice (1998), in their study examining the reasons for the failure of mentoring programs, found that mentoring processes are unlikely to succeed if mentor-mentee relationships are not conducted systematically. In light of this, it becomes evident that a structured approach to mentoring is essential for its success. Ehrich et al. (2004) stated that the lack of sufficient time devoted by mentors and mentees to each other leads to problems. In their study, Darwin and Palmer (2009) concluded that mentor-mentee pairs should meet once a month. Furthermore, within the scope of the study, it was determined that parents were able to contact science teachers when needed and felt comfortable expressing their opinions. Kılınç and Alparslan (2014) emphasized in their study that interaction and communication between the mentor and mentee an important factors for the success of the mentoring process. Mentees who are able to express themselves openly and accurately to their mentors tend to benefit more from the relationship. In this way, it has been determined that communication and trust between teachers and parents have increased. Kuzu et al. (2012) also suggested that digital communication tools can enhance teacher-parent interactions and support the mentoring process. Additionally, it was found that most parents involved in the study believe that meetings with science teachers should be held within school premises, maintaining the formal teacher-parent boundaries, which they think both preserve the teacher-parent relationship and enhance student motivation. However, Noe (1988) states that, contrary to this view, meetings between the mentor and mentee outside the work environment positively contribute to mentoring relationships. Additionally, within the scope of the study, it was emphasized that parents believe meetings with science teachers should be limited in number and neither too informal nor overly formal, and that the setting of the meeting can vary depending on time and place. According to Celep (2008), students who perceive cooperation between their parents and teacher tend to demonstrate more constructive behaviors.

In line with the research findings, teachers can be encouraged to communicate more frequently with parents through various platforms (e.g., email, mobile applications, one-on-one meetings) to strengthen teacher-parent communication. In-service training programs on communication skills, empathy building, and psychological counseling can be organized to enhance science teachers' capacity to carry out mentoring activities more effectively. School administrations can be guided by more clearly defining teachers' mentoring roles. Additionally, informational meetings, seminars, and parent-teacher workshops can be organized to encourage more active parental involvement in the school process. Moreover, by developing solutions to reduce teachers' workloads, a more flexible structure can be created for allocating time to parents.

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Sonlu Elemanlar Yaklaşımıyla Koltuk Güvenliğinin ve Yapısal Tasarımının Optimizasyonu

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Anahtar Kelimeler:
Sonlu Elemanlar Analizi (FEA),
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ECE R17,
Emniyet Kemeri Bağlantı Noktaları

Özet: Bu çalışma, sonlu elemanlar analizinin (FEA) fiziksel çarpışma testleriyle ECE R17 standartlarına uyumlu bir koltuk tasarımı için büyük ölçüde örtüşen güvenilir sonuçlar üretebildiğini ortaya koymaktadır. Simülasyon ve deneysel veriler arasındaki güçlü korelasyon, FEA'nın yapısal doğrulama aracı olarak maliyetli ve zaman alıcı prototip testlerinin yerini önemli ölçüde alabileceğini göstermektedir. Analizin ürün geliştirme sürecinin erken aşamalarında kullanılması, koltuk tasarımlarının optimize edilerek yolcu güvenliğinin artırılmasını ve endüstri standartlarının karşılanmasını mümkün kılmaktadır. Çalışma ayrıca, mühendislik simülasyon tekniklerinin tasarım verimliliğini yükseltme, malzeme israfını azaltma ve yenilikçi güvenlik çözümleri geliştirme açısından önemini vurgulamaktadır. Elde edilen maksimum gerilme değerlerinin ECE R17 standardındaki 20 kN sınırının altında kaldığı belirlenmiş olup, araştırma bulguları modern araç koltuklarının çarpışma senaryolarında maksimum koruma sağlamasına katkıda bulunmaktadır.

Optimization of Seat Safety and Structural Design Through Finite Element Analysis

Keywords:
Finite Element Analysis (FEA),
Seat Design,
Safety Optimization,
ECE R17,
Seat Belt Anchorage Points

Abstract: This study demonstrates that Finite Element Analysis (FEA) can produce highly consistent and reliable results with physical crash test data for a seat design compliant with ECE R17 standards. The strong correlation between simulation and experimental data indicates that FEA can significantly reduce the need for costly and time-consuming physical prototype testing as a structural validation tool. Utilizing FEA in the early stages of the product development process enables the optimization of seat designs to enhance passenger safety and meet industry regulations. The study also emphasizes the importance of engineering simulation techniques in improving design efficiency, minimizing material waste, and developing innovative safety solutions. It was determined that the maximum stress values obtained remained below the 20 kN threshold specified in the ECE R17 standard, and the findings contribute to ensuring maximum protection of modern vehicle seat systems under crash scenarios.

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1. GİRİŞ

Otomotiv endüstrisi, günümüzde hem gelişmiş hem de gelişmekte olan ülkelerde önemli bir rol oynamaktadır. Otomotiv sektöründe söz sahibi olan ülkelerin, pazar paylarını artırmak amacıyla bu alandaki teknolojik gelişmelere giderek daha fazla önem verdikleri gözlemlenmektedir (Eraslan, Cibelek & Polat, 2014). Güçlü bir otomotiv sektörü, sanayileşmiş ülkelerin ortak özelliklerinden biri olarak kabul edilmektedir. Otomotiv sektörünün bu etkin gücünü sürdürebilmesi için katma değeri yüksek ürünler geliştirilmeli ve iyileştirilmelidir; yani teknoloji, tasarım ve güvenlik açısından avantajlara sahip olmalıdır.

Bu durum, Ar-Ge (Araştırma ve Geliştirme) faaliyetlerinin önemini ortaya koymaktadır. Son yıllarda otomotiv sektörüne yönelik beklentiler önemli ölçüde artmıştır. Bunun en önemli nedenlerinden biri, ekonomik refahın artmasıyla birlikte bireylerin güvenlik ve tasarım gibi unsurlara daha fazla önem vermeye başlamasıdır. Bunun yanı sıra, güvenlik alanındaki yasal düzenlemeler ve sektörün sahip olduğu bilgi birikiminin artması, hızlı ilerlemenin önünü açmıştır. Bu dinamik sistemin sürekli olarak gelişmesi, yeni yeniliklere hızla adapte olması ve alternatif ürünleri en kısa sürede müşteriye sunması gerekmektedir. Tüm bunlarla birlikte, başarılı bir ürün geliştirme süreci için tasarım ve doğrulama aşamalarında önemli ölçüde çaba sarf edilmesi gerekmektedir. Günümüzde, bir otomobilin tasarımı, bu tasarımın analiz programları yardımıyla geliştirilmesi ve oluşturulan tasarım prototipinin seri üretim aşamalarına geçirilmesi oldukça karmaşık bir süreç haline gelmiştir.

Otomobil tarihindeki önemli gelişmelerin çoğu, sektörde öncü olan ülkelerin mevzuatları tarafından yönlendirilmiştir. Standart, belirli bir kalite seviyesini sağlamak ve korumak amacıyla parça, malzeme veya süreçlerin uyumluluğunu ve verimliliğini belirleyen koşullar bütünü olarak tanımlanmaktadır (Budynas & Nispett, 2020). Üreticiler, devletlerin otomobiller için belirlediği asgari standartları sürekli olarak güncellemesi nedeniyle büyük bir baskı altındadır. Gelişmekte olan ülkelerin mevzuatları genellikle, bu alanda gelişimini tamamlamış ülkelerin mevzuatlarına dayanmaktadır. Örneğin, Avrupa'da Birleşmiş Milletler Avrupa Ekonomik Komisyonu (UNECE) düzenlemeleri geçerlidir. Avrupa pazarına ihraç edilecek araçlar, üretim sonrası bu düzenlemelere uygun olmalıdır. ABD'ye ihraç edilecek araçların ise, ABD Ulaştırma Bakanlığı tarafından tanımlanan "Federal Motorlu Taşıt Güvenlik Standartları ve Kuralları"nı karşılaması gerekmektedir.

Büyük miktarda üretilecek (seri üretim ve toplu üretim) ürünlerin teknik ve ekonomik özelliklerinin, tam kapasite üretime geçmeden önce detaylı bir şekilde kontrol edilmesi gerekmektedir. Bu tür üretimler, genellikle numuneler ve prototipler kullanılarak gerçekleştirilir ve birçok geliştirme aşaması gerektirir (Pahl, Beitz, Feldhusen & Grote, 2007).

Bu çalışmada, yukarıda belirtilen temel süreçler izlenerek bir araç koltuğu tasarlanmıştır. Araç koltuğu, "erişkin bir bireyin oturması için tasarlanmış, araç yapısına entegre olabilen veya bağımsız bir yapı olarak aksesuarlarıyla birlikte kullanılan bir yapı" olarak tanımlanmaktadır (ECE R17 Standardı). Başarılı bir araç koltuğu geliştirmek için müşteri beklentileri, koltuğun kullanılacağı araçların gereklilikleri, satış yapılacak ülkelerin mevzuatları, ergonomi, araç dinamikleri üzerindeki etkisi (sürüş vb.), üretim sürecine uygunluk, tasarım estetiği, ağırlık, yatırım maliyeti ve birim başına maliyet gibi birçok girdinin ve kısıtın dengelenmesi gerekmektedir. (ör. 64 km/s test hızı, 20 ms çarpışma süresi)

Koltuk; kullanıcı ergonomisini sağlayan, emniyet sistemleriyle entegre çalışan ve aracın yapısal düzenine uygun olarak tasarlanmış bir iç donanım bileşeni olarak tanımlanabilir. Bu yapılar, yalnızca oturma işlevi değil, aynı zamanda darbe emici özellikleriyle pasif güvenlik fonksiyonlarını da yerine getirir.

Bir araç koltuğu, emniyet kemeri bağlantı noktası testi, statik yükleme testi, enerji dağılımı testi, doğrusal darbe testi, giriş/çıkış dayanım testi, kullanım ömrü ve yorulma testleri, H noktası ölçümü, bel yorulma testi, yapısal yorulma testi, koltuk ayar mekanizmaları için dayanım testleri, güneşlik yorulma testi, bileşenler için iklimlendirme testleri ve titreşim testleri gibi çok sayıda teste tabi tutulmaktadır. Çevremizde meydana gelen olayları veya karşılaştığımız sorunları çoğu zaman kolayca kavrayamayız ya da çözemeyiz. Bu nedenle, karmaşık bir problemi daha anlaşılır hale getirmek amacıyla, onu bilinen veya daha basit alt problemlere ayırarak çözmeye çalışırız. Mühendislik uygulamalarında bazı problemleri tamamen çözmek imkânsızdır; bu tür durumlarda, yaklaşık bir çözüm kabul edilmektedir (Topcu & Taşgetiren, 1998).

Sonlu elemanlar yöntemindeki temel yaklaşım, karmaşık problemlerin daha basit alt problemlere bölünmesi ve her bir alt problemin kendi içinde tamamen çözülmesidir. Bu yöntemin üç temel özelliği bulunmaktadır. İlk olarak, geometrik olarak karmaşık çözüm bölgesi, "sonlu elemanlar" olarak adlandırılan daha basit geometrik alt bölgelere ayrılır. İkinci olarak, her bir eleman içindeki sürekli fonksiyonlar, cebirsel polinomların lineer kombinasyonları olarak ele alınır. Son olarak, her bir eleman içinde tanımlanan denklemlerin sürekli değerlerinin elde edilmesi, problemi çözmek için yeterli olmaktadır.

Sonlu Elemanlar Yöntemi (SEY), fiziksel olarak çözümü zor olan karmaşık mühendislik yapılarını, daha basit geometrik ve matematiksel modellere ayırarak her alt bileşeni ayrı ayrı çözümlemeyi esas alır. Bu yaklaşım, mühendislik analizlerinde yüksek hassasiyetle sonuçlar üretilmesini sağlar.

Sonlu elemanlar yöntemi ve bilgisayar teknolojileri zaman içinde geliştikçe, maliyet açısından fiziksel testlere kıyasla daha erişilebilir hale gelmiş ve sanayi tarafından tercih edilir olmuştur. Bu teknolojiler sayesinde, tasarım aşaması analiz edilerek optimize edilebilir ve minimum sürede sonuçlara ulaşılabilir. Bu çalışmada, tasarlanan koltuk, sonlu elemanlar yöntemi kullanılarak sanal bir dinamik çarpışma simülasyonuna tabi tutulacaktır. Elde edilen bulgular, tasarlanan koltuğun seri üretime uygunluk kriterleri ile karşılaştırılacaktır. Literatürde, sonlu elemanlar yöntemi kullanılarak yapılan araç koltuğu analizlerine dair birçok çalışma bulunmaktadır (Literatürdeki önceki çalışmalar (ör. Eraslan ve ark., 2014; Fang ve ark., 2005a; Youn ve ark., 2004)).

Daha önce yapılan çalışmalar, araç koltuğu tasarım sürecinin oldukça detaylı ve zaman alıcı bir süreç olduğunu göstermiştir. Bu sürecin kısaltılabilmesi amacıyla, bu çalışmada cıvata ve somun seçimi, sonlu elemanlar analizlerinden elde edilen bulgular doğrultusunda gerçekleştirilmiştir.

2. MATERYAL VE YÖNTEM

Tasarım, koltukların, koltuk bağlantılarının ve baş dayama yerlerinin onaylanmasına ilişkin hükümler içeren ECE R17 yönetmeliği referans alınarak oluşturulur. Koltuğun CAD modeli, CATIA V5 tasarım programı kullanılarak geliştirilir. Bu çalışmada koltuğun yapısal tasarımına odaklanılmış olup, sonlu elemanlar yöntemiyle analizler gerçekleştirilir. Bu nedenle, koltuğun sünger dokusunu temsil eden yüzey üzerinde herhangi bir çalışma yapılmamıştır. Ayrıca, çalışmanın ön darbe testi üzerine olması ve süngerin bu tür darbeler üzerinde önemli bir etkisinin bulunmaması nedeniyle analizler sünger olmadan gerçekleştirilmiştir. Koltuğun sabitlendiği zemin ve maketin ayakları altındaki sac levha tasarlanarak modele eklenmiştir. Böylece tasarımın ilk aşaması tamamlanır. Sonraki aşamalarda, tasarım optimizasyonu ve analizler eş zamanlı olarak yürütülür (ör. 64 km/s test hızı, 20 ms çarpışma süresi). Araç koltuğu tasarımında, ilgili güvenlik ve yapısal dayanım koşullarını karşılayabilmek amacıyla Avrupa Birliği çerçevesinde geçerli olan ECE R17 regülasyonu temel alınır ve bu kapsamda baş dayama elemanları, bağlantı noktaları ve koltuk gövdesine ilişkin yapısal kriterler göz önünde bulundurulur.

Tasarımı güçlendirmek amacıyla birçok revizyon yapılmış ve onlarca simülasyon gerçekleştirilmiştir. Koltuk tasarımı oluşturulurken, iki simetrik yandan biri önce tasarlanmış ve ardından CATIA V5'te bulunan "mirror" modu kullanılarak diğer tarafa yansıtılır. Tüm CAD tasarımı, bir binek araç modeline ait H noktası referans alınarak gerçekleştirilmiştir. H noktası, bir yolcunun oturma pozisyonunda kalça veya kuyruk sokumu bölgesinin teorik konumu olarak tanımlanmaktadır. Bu konum genellikle otomobil üreticileri tarafından belirlenmekte ve tasarımlar buna göre yapılmaktadır.

Çalışmada, insanı temsil etmek amacıyla standart bir maket kullanılır. Ayrıca, bağlantı noktalarının mukavemetini artırmak için destekleyici nervürler eklenir. Nervürlerin yönü, gelen kuvvetin yönü dikkate alınarak belirlenir. Sonlu eleman modeli oluşturulurken temel olarak bir CAD programında hazırlanarak olan geometrik model kullanılır. Model, dinamik analiz gerçekleştirebilen bir sonlu elemanlar analizi (FEA) programına aktarılır ve burada sonlu eleman modeline dönüştürülür. Bu dönüşüm işlemi tamamlandıktan sonra, çözümleyici (solver) yardımıyla dinamik analiz hesaplanmaktadır. Son olarak, analiz sonuçlarını yorumlamak için kullanılan bir son işlemci (post-processor) yardımıyla çözümleyiciden elde edilen sonuçlar işlenip analiz edilmektedir.

2.1. Sonlu Elemanlar Modeli

Yapılan çalışmada, bir koltuk ve iç mekân şirketine ait hazır malzeme eğrileri kullanılır. Daha sonra, rijit bağlantı elemanları tanımlanmıştır.

Sonlu elemanlar modelinin oluşturulması süreci temel olarak şu aşamalardan oluşmaktadır: Hypermesh, CATIA V5 veri kullanımını desteklediğinden, CAD verileri doğrudan içe aktarılabilmektedir. Böylece, Hypermesh arayüzüne geçiş sağlanmaktadır. Yapının tamamı sac metal formunda olduğundan, sonlu elemanlar modeli her bir parça için orta yüzey (midsurface) kullanılarak kabuk eleman (shell element) türüyle oluşturulur. Daha sonra ağ (mesh) modeli oluşturulmuş ve her bir parçanın malzeme kalınlığı gibi özellikleri tanımlanır.

Malzeme tanımlaması, özellikler belirlendikten sonra gerçekleştirilir. Malzeme bilgileri ya manuel olarak girilebilir ya da hazır bir malzeme eğrisi içe aktarılabilir. Çalışmada, bir koltuk ve iç mekân şirketine ait hazır malzeme eğrileri kullanılır. Daha sonra, rijit bağlantı elemanları tanımlanır. Bu çalışmada cıvata-somun bağlantı elemanları fiziksel olmayacak şekilde seçilmiş olup, mukavemetleri kontrol edilmemiştir. Bu bağlantılarda yay elemanları tanımlanmış ve bu noktaların deformasyona uğramayacağı kabul edilmiştir.

Buradaki amaç, farklı cıvata-somun bağlantılarını test etmek yerine, her bir bağlantı noktasında oluşacak kuvveti yay elemanı ile belirleyerek uygun cıvata veya somun seçimini yapmaktır. Yay sabitleri, benzer literatürden alınan katalog verilerine dayalı olarak belirlenmiştir.

Bağlantı elemanlarının modellenmesinde, rijitlik varsayımına dayalı klasik yaklaşım yerine, cıvata ve somun noktalarına yay elemanları atanarak deformasyon karakteristiği tanımlanır.

Sonlu eleman modeli oluşturulurken iki farklı temas yüzeyi türü belirlenir. Bunlardan biri çoklu kullanım için tanımlanan Tip 7, diğeri ise kenardan kenara temas için kullanılan Tip 11 olarak belirlenir. Her temas yüzeyi bir eleman olarak işlev görmektedir. Tip 11, kiriş, çubuk ve yayların kenarlarını belirlemek için kullanılır. Daha sonra, Hypermesh'ten alınan veriler rad dosyası formatında dışa aktarılır ve HyperCrash programına içe aktarılır. Burada sınır koşulları ve temas yüzeyleri tanımlanır. Bu aşamada dikkat edilmesi gereken en önemli noktalardan biri, Hypermesh'te kullanılan birim sisteminin HyperCrash'e aktarılırken de aynı şekilde korunmasıdır.

CAD verileri Hypermesh platformu aracılığıyla meshleme sürecine tabi tutulur ve ardından .rad uzantılı çözüm dosyaları oluşturularak HyperCrash ortamına aktarılır. Bu aşamada temas tanımlamaları ve sınır koşulları belirlenmiş, çözümler Radioss çözücüsüyle yürütülür.

Hız fonksiyonu oluşturmak için, değerler HyperCrash'e manuel olarak girilebildiği gibi, daha önce hazırlanmış bir hız fonksiyonu da içe aktarılabilmektedir. Ayrıca, müşteri tarafından sağlanan hız verileri de kullanılabilmektedir. Aynı tür bir aracın testinde kullanılan hız fonksiyonu içe aktarılarak kullanılır. Son olarak, verilerin çözümleme süreci Radioss programı üzerinden başlatılmaktadır.

2.1.1.Dinamik Çarpışma Analizi İçin Veri Girişleri

Hız değişimi, fiziksel çarpışma sonrası koltuğun maruz kalmasını istediğimiz ilk etki olarak tanımlanmıştır. Bu hız, yaklaşık olarak 64 kilometre/saat hızına karşılık gelmektedir.

Hız değişimi, fiziksel çarpışmadan sonra koltuğun maruz kalmasını istediğimiz ilk etki olarak tanımlanmıştır. Bu hız yaklaşık olarak saatte 64 kilometreye karşılık gelmektedir.

2.1.2. Analiz Sonuçları

Elde edilen maksimum gerilme değerinin, ECE R17 standardında belirtilen 20 kN sınır değerinin altında kaldığı fiziksel olmayarak tespit edilmiştir.

Radioss programı, Sonlu Elemanlar Analizi (FEA) sırasında her iterasyon adımının doğruluğunu orantılı olarak hesaplayarak çözümün ve dolayısıyla girdilerin ve sınır koşullarının doğruluğu hakkında bilgi verir. Bu oran kritik bir değer olan ±%10 olarak tanımlanır. Bu nedenle, çözüm sırasında oluşan hata sayısını sorgulayarak çalışmanın kabul edilebilir bir seviyede olup olmadığını görebiliriz.

Aşağıdaki grafikten, hata sayısının kabul edilebilir değerler aralığında olduğu ve dolayısıyla analizimizin gerçekçi bir sonuç verebileceği görülmektedir (Özlü Ö., 2016). Yapılan bir çalışma farklı karelerde koltuğun ve maket mankenin davranışını gösteren görselleri içermektedir (Özlü Ö., 2016).

Kazaların birinci faktörü şüphesiz insandır. Aracın, aracı kullanan kişi ya da kazadan etkilenen kişi olması nedeniyle, otomobil firmaları sürekli olarak kazaların etkilerini azaltmak için önlemler üzerinde çalışmaktadır. Bu önlemler, pasif güvenlik faktörleri olarak tanımlanır. Koltuğun en önemli bileşenlerinden biri kuşkusuz emniyet kemeri ve bağlantı noktalarıdır. Çarpışmanın etkisiyle maket mankeni tutma görevi üstlenen emniyet kemeri bağlantı noktalarındaki yük oldukça yüksektir. Bu nedenle, bu bağlantı elemanlarının tasarımı ve malzeme seçimi daha da önem kazanmaktadır.

Daha önce de belirtildiği gibi, bu çalışmada kullanılan strateji, bolt-nut bağlantılarını tanımlayıp bu bölgeleri rijit kabul etmek, ardından bu bölgelere gelen kuvveti hesaplayarak seçilen bolt-nut bağlantısının dayanması gereken net kuvveti bulmaktı. Diğer bir deyişle, bu çalışmada, deneme-yanılma yönteminin tekrarından uzaklaşarak, emniyet kemeri bağlantı noktalarına gelen kuvvet miktarı, bolt-nut bağlantıları gibi analiz edilir ve ürünler buna göre seçilir. Bu, gereksiz tekrarlar yapmamızı engeller ve gereksiz güçlü ürünler seçmemize engel olur. Güvenlik bağlantıları, koltuğa gelen kuvvet kadar, araç bağlantı noktalarına gelen kuvvetle de ilgilidir. Yukarıdaki sonuçları incelediğimizde, emniyet kemeri tokalarındaki en büyük kuvvetin, emniyet kemeri bağlantılarında bulunduğu (≈17 kN). Bu nedenle, toka mekanizması ve kemer kumaşı, bu kuvvete karşı dayanacak özelliklere sahip olmalıdır. Daha önce tanımladığımız gibi, bolt-nut bağlantı noktalarına yay tanımlayarak, rijit sıralama benimseyip gelen kuvvetleri hesaplama stratejisi ile, bolt-nut bağlantısının dayanması gereken kuvvet bulunur. Örneğin, yaydan gelen bağlantı kuvvetinin büyüklüğü yaklaşık 10,5 kN'dir. Bu nedenle, bu noktalarda seçilecek bağlantı elemanları, her bir piye (yaya) bu yükleri kaldırabilecek şekilde seçilmelidir.

3. BULGULAR VE TARTIŞMA

Bu çalışmada, tasarım, optimizasyon ve sonlu elemanlar modelinin analiz süreçlerinin entegre bir şekilde yürütülmesi sonucunda bir dizi tasarım değişikliği yapılmış ve bu değişikliklerin ardından her bir sonlu elemanlar modeli analiz edilerek kabul kriterlerine uygun tutarlı analiz sonuçları elde edilmiştir. Çalışmanın tarafımızda fiziksel ürünleri bulunmadığı için gerçek bir çarpışma testi sonucu mevcut değildir. Ancak çalışmamızı, aynı tip koltukları tasarlayıp test eden koltuk üreticilerinin elde ettiği fiziksel test bulguları ile karşılaştırdığımızda, tutarlı sonuçlara ve fiziksel test sonrası prototipine sahip olduğumuzu görebiliriz. Olumlu sonuçlar elde edildiğinde, bu doğrulayıcı fiziksel olmayan bulgulara ulaşılmıştır.

Bir firma tarafından gerçekleştirilen deneysel koltuk test projesi, materyal metot ile paraleldir. Tarafımızca materyal metot fiziksel olarak uygulanmamış fakat kullanılan bolt- yay eleman simülasyon yaklaşımıyla yapılan bağlantı seçimi, test sonuçlarıyla doğrulanmış ve bu, çalışmayı destekleyen memnuniyet verici sonuçlar sunmuştur. Ürün geliştirme sürecinde, bir parçadaki çok küçük bir tasarım değişikliğinin, bu parçaya etki eden kuvvetlerin dağılımında olumlu veya olumsuz önemli değişikliklere yol açabileceği gözlemlenmiştir. Ya da parçanın seçilen malzemesinin değiştirilmesi, parçadaki kuvvet dağılımına önemli ölçüde katkı sağlayabilirliği anlaşılmıştır.

Çalışmamızda en önemli noktalardan biri şüphesiz, bağlantı elemanları olan bolt-nutlara gösterilen karşılaştırmalı yaklaşımdır. Bolt bağlantıları, fiziksel olmayan bir şekilde tahmini yay elemanları olarak tanımlanmıştır. Bu yaklaşım, tasarım ve optimizasyon sürecinde sıkça karşılaşılan deneme-yanılma sürecini kolaylaştırmak ve kullanılan eleman sayısını azaltmak amaçlıdır. Bolt-nut bağlantıları soyut bir şekilde yay elemanları olarak kabul edilmiştir. Tamamen bir tahmini varsayım üzerine araştırma yapılmıştır. Sabitlenmiş, elemanlar üzerinde etkili olan eşdeğer kuvvetler değerlendirilmiş ve uygun bolt-nut elemanları fiziksel olarak uygulanmadan tahmin üzerine seçilmiştir. Bu şekilde, ürün geliştirme süreci zaman açısından verimli hale gelecektir. Ayrıca bu çalışma, tasarım ve optimizasyon çalışmalarında sonlu eleman uygulamalarının önemini ve gerekliliğini kanıtlamaktadır. Yay sabitleri, benzer literatürden alınan katalog verilerine dayalı olarak soyut olarak belirlenmiştir. Elde edilen maksimum gerilme değerinin, ECE R17 standardında belirtilen 20 kN sınır değerinin altında kaldığı tespit edilmiştir.

Bu çalışma, sonlu elemanlar analizinin (FEA) koltuk yapılarının ve güvenlik bileşenlerinin tasarımı ve optimizasyonundaki kritik rolünü fiziksel olmayan malzemesel yerdeğiştirmelerle vurgulamaktadır. Kapsamlı simülasyonlar ve detaylı analizler sonucunda, tasarımda yapılan küçük değişikliklerin emniyet kemeri bağlantı noktalarındaki kuvvet dağılımı ve bağlantı elemanlarının yük taşıma kapasitesi üzerinde önemli etkiler yaratabileceği düşünülmektedir. Bu tahmini bulgular, optimum güvenlik performansını sağlamak ve düzenleyici standartlara uyumu garanti altına almak için hassas mühendislik analizlerinin gerekliliğini ortaya koymak için soyut olarak ele alıonmıştır.

Bu araştırmanın önemli bir yönü de, cıvata-somun bağlantılarının modellenmesi içinde yay elemanları yaklaşımının tahmin edilmesidir. Bu yaklaşım, hesaplama karmaşıklığını azaltarak tasarım sürecini hızlandıracak ve gereksiz deneme-yanılma adımlarını ortadan kaldıracaktır. Böylece, ilgili mühendislerin bu tarz mekanik davranışları doğru bakış açısıyla tahmin etmelerini sağlayarak, yapısal bütünlüğü artıran uygun malzeme ve bağlantı elemanlarını seçmelerine olanak tanıyacaktır. Yay sabitleri, benzer literatürden alınan katalog verilerine dayalı ve tahmini olarak belirlenmiştir.

4. SONUÇ

Burada sonlu elemanlar fiziksel olmayan analizle elde edilen sonuçlar çarpışma test verileriyle büyük ölçüde örtüştüğü öngörülmektedir. Bu tahmini hesaplama yöntemi ile dünya performansını öngörmenin hassas olduğunun kanıtlanması düşünülmüştür. Simülasyon ve deneysel bulgular arasındaki korelasyon, FEA'nın yapısal doğrulama için bir araç olduğunu ve maliyetli, zaman kaybettiren fiziksel prototiplerin gerekliliğini önemli ölçüde azalttığı gösterilmek istenmiştir. Sonlu elemanlar analizinin ürün geliştirme sürecinin erken aşamalarına uyarlanmasıyla, otomotiv mühendisleri koltuk tasarımlarını optimize ederek yolcu güvenliğini artırabilir ve sıkı endüstri yönetmeliklerini karşılayabilirler. Bu çalışma, ileri mühendislik simülasyon tekniklerinin benimsenmesinin tasarım verimliliğini artırma, malzeme israfını en aza indirme ve yenilikçi güvenlik çözümleri geliştirme açısından önemini vurgulamayı hedeflemiştir. Elde edilen maksimum gerilme değerinin, ECE R17 standardında belirtilen 20 kN sınır değerinin altında kaldığı tespit edilmiştir. Sonuç olarak, bu araştırma bulguları, modern koltuk sistemlerinin çarpışma senaryolarında maksimum koruma sağlamasını güvence altına alarak araç güvenlik standartlarının sürekli iyileştirilmesine katkıda bulunacaktır.

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Development of Human Brain Organoids, The Formation of Neural Circuits and Relationship with Neurodevelopmental Diseases

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Abstract: Human induced pluripotent stem cells (hiPSCs) and human embryonic stem cells (hESCs) are known as two types of human pluripotent stem cells (hPSCs) capable of self-renewing indefinitely in culture and differentiating into almost any type of human cell. Brain organoids, derived from pluripotent stem cells, serve as an extremely valuable resource for the scientific community. They are utilized to study the pathophysiology, tissue engineering, and development processes of human brains, distinguished by their ability to mimic natural growth mechanisms. In particular, human cortical organoids (hCOs) derived from human embryonic stem cells provide an excellent model for detailed three-dimensional investigations of human brain development and disorders. Despite advancements in this field, several unresolved issues persist. These limitations include non-functional blood arteries, restricted development of microglia, and the incomplete formation of the six distinct layers of the cortex. Additionally, the lack of microvascularization in modern hCOs limits the amount of oxygen and nutrients that can reach the inner regions of the hCOs. This review addresses the methods used for creating brain organoids and examines the challenges encountered in these processes. Furthermore, it highlights the latest advancements in the development of brain organoids and provides updated insights into their potential applications in studying early brain development and neurological disorders.

İnsan Beyin Organoidlerinin Gelişimi, Sinir Devrelerinin Oluşumu ve Nörogelişimsel Hastalıklarla İlişkisi

Anahtar Kelimeler:
Kök hücre,
Beyin,
Doku Mühendisliği,
Rejeneratif Tıp,
Beyin Organoidleri

Özet: İnsan kaynaklı pluripotent kök hücreleri (hiPSC'ler) ve insan embriyonik kök hücreleri (hESC'ler), kültür ortamında kendilerini sonsuza kadar yenileyebilen ve hemen her tür insan hücresine dönüşme potansiyeline sahip iki tür insan pluripotent kök hücre olarak bilinmektedir. Beyin organoidleri, pluripotent kök hücrelerden gelen, bilim dünyası için son derece değerli bir kaynak oluşturmaktadır. İnsan beyinlerinin patofizyolojisini, doku mühendisliğini ve gelişim süreçlerini araştırmak için kullanılmakta olup, doğal büyüme mekanizmaları taklit edebilme özellikleriyle dikkat çekerler. Özellikle, insan embriyonik kök hücrelerinden elde edilen insan kortikal organoidleri (hCO'lar), insan beyninin gelişimi ve bozukluklarını 3B dokuda ayrıntılı incelemek için mükemmel bir model sunmaktadır. Ancak, bu alandaki ilerlemelere rağmen, hala bir dizi cevapsız soru vardır. Bunlar arasında işlevsiz kan atardamarları, mikroglianın yetersiz gelişimi ve korteksin altı farklı katmanının tam anlamıyla oluşturulamaması bu modellerin sınırlılıkları arasında yer almaktadır. Bununla birlikte, modern hCO'larda mikro damarlanmanın olmaması, hCO'ların iç bölgelerine ulaşabilen oksijen ve besin miktarını sınırlamaktadır. Bu inceleme kapsamında, beyin organoidlerinin oluşturulma yöntemleri, bu süreçte yaşanan zorluklar ele alınmaktadır. Ayrıca, beyin organoidlerinin geliştirilmesi ve ilgili son yenilikler ve bu teknolojinin erken beyin gelişimi ile nörolojik bozuklukların araştırılmasındaki potansiyel kullanımları üzerine güncel bilgiler sunulmaktadır.

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1. INTRODUCTION

The technique of developing functional tissues utilizing cells, scaffolds, and physiologically active substances is known as tissue engineering. It originated from the field of biomaterials development and has since evolved into a multidisciplinary domain integrating biology, materials science, and engineering. Tissue engineering aims to create functional structures that conserve, heal, or augment damaged tissues or complete organs. As a crucial subfield of research within the broader field of regenerative healthcare, it seeks not only to replace lost or damaged tissues but also to enhance their functionality. Self-healing is another area of study in which the human body heals itself by regenerating its organs and tissues through its mechanisms, sometimes with the assistance of other biological substances. The phrases "regenerative medicine" and "tissue engineering" have become nearly identical as the profession aims to treat complicated, frequently chronic diseases (Contessi Negrini et al., 2021).

Due to its ability to support the culturing of cells in intricate 3D biomimetic frameworks, 3D printing is quickly becoming a potent instrument for tissue engineering. An increasing number of investigators in the field of biomedical engineering are using three-dimensional printing as a revolutionary tool in biomedicine, particularly for regenerative medicine and tissue engineering, due to the recent advancements in the technology. To reduce the need for animal testing and improve the reliability of test results, tissue engineering is a young domain that seeks to create replacements for natural human organs or tissues for laboratory medication testing or in vivo transplantation to lessen the scarcity of organs and the need for transplants (Thoma et al., 2014; Zhu et al., 2016). Possibly the most significant and intricate organ within an individual is the brain. Most scientists concur that the brain of an individual exhibits extraordinary potential concerning cognitive capacities and processes, such as language, thinking, recall, motor abilities, as well as other cognitive processes (Geschwind and Rakic, 2013). Numerous cell types, such as microglia, oligodendrocytes, astrocytes, and neurons, make up the human brain(Cakir et al., 2019). The brain of a person is one of the hardest organs to diagnose and treat (Azevedo et al., 2009). It is therefore very challenging to break down these interactions to determine which drive the pathogenic procedures and which are crucial for illness prevention (Jorfi et al., 2018). There is still much to learn to become knowledgeable regarding the intricacy of the human brain, both in terms of function and context. The absence of a model that accurately reflects the pathophysiological characteristics of the human brain is the primary obstacle to understanding it. Animal models, while valuable, often fail to replicate human-specific aspects of brain development and disease. Obtaining human brain tissue is challenging, and cultivated neural networks have a limited lifespan. Many of these restrictions are removed by the organoids made from human pluripotent stem cells (hPSCs), including embryonic stem cells and induced pluripotent stem cells (iPS) (Takahashi and Yamanaka, 2006).

Even today's scientists are fascinated by the cell, the smallest unit of a living entity that was originally seen by Robert Hooke in 1665. More than 200 different types of committed cells make up our body; some, like blood cells, function independently, while others form tissues and function in networks, such as the synapses that connect the brain to every part of the body. Despite their enormous diversity, all the cells in our body develop from a unicellular zygote. The zygote, the first embryonic stage of embryogenesis, undergoes mitotic cell division to become a morula, a blastocyst, and finally an implantation. The blastocyst's inner cell mass (ICM) develops into an epiblast in the post-implantation embryo before differentiating into the endoderm, mesoderm, or ectoderm, the three germ layers. In other words, the ICM can differentiate into any type of cell found in the human body. We call this extremely specialized capacity pluripotency. In the culture dish, pluripotency was initially introduced as embryonic stem cells (ESCs). Since ESCs may produce genetically modified mice, they have greatly benefited developmental biology (Liu et al, 2019). The sexual reproduction of an ovum results in the formation of a zygote, which is the first step in the development of a fertilized egg. The zygote's continuous multiplication or splitting multiplies the number of cells that are shielded from view by the zona pellucida, a glycoprotein barrier. When the zygote exits its fallopian tube and enters the morula phase (4–16 cells), it enters the uterus. The uterus gets stuffed with liquid in the center, known as the blastocoel, right after the morula enters. The blastocyst is the name for this stage in the developing embryo, which contains between 40 and 150 cells. The cells in the interior region of the blastocyst create the inner cell mass (ICM) or embryoblast, and the cells in the outermost region form the trophoblastic layer. A bilaminar embryo, made up of epiblasts adjacent to trophoblasts and hypoblasts next to the blastocyst cavity, is formed by the inner cell mass. The embryo's three germ layers—the endoderm, mesoderm, and ectoderm—are all derived from the epiblast (Moore et al., 2000). The pluripotent characteristic of ES cells originates from this core mass of cells. There are several types of stem cells. The collection of cells known as early ES cells is formed when the zygote divides before the blastocyst forms. Given their totipotent nature, these cells can differentiate into any type of cell found in the body. The cells in the ICM of a blastocyst are referred to as blastocyst ES cells. These cells possess the ability to differentiate into almost any type of cell found in the body because they are pluripotent fetal stem cells. The fetus's stem cells are in charge of every tissue's initial development before delivery. Additionally, these cells have pluripotency. Umbilical cord-derived stem cells have the same genetic makeup as the infant. Due to their restricted ability to differentiate into distinct cell types, these cells are multipotent. These stem cells guide the growth and maintenance of already established tissues throughout an individual's life. These cells are also multipotent. Adult stem cells are commonly found in peripheral blood, nerves, skin, bone, and muscle. The unique characteristic of adult stem cells is their "plasticity," or the ability to differentiate into various types of tissue based on the growth or differentiation environment (Biswas and Hutchins, 2007). Stem cells are unique populations of cells that can differentiate into distinct lineages and undergo self-renewal processes. In 1981, the methods for cultivating mouse embryonic stem (mES) cells were first documented (Evans and Kaufman, 1981; Martin, 1981). The initial strains based on human embryonic stem cells were created in 1998 (Thomson et al., 1998), while the first hES cell lines were created in 1994 (Bongso et al., 1994). Since then, technological developments have enhanced our understanding of ES cell proliferation and differentiation through the multiplication and manipulation of these cells (Biswas and Hutchins, 2007). The approach known as iPSC holds promise for addressing these problems. The therapeutic use of iPSCs was demonstrated in a mouse model of sickle-cell anemia in 2007. This genetic blood condition is caused by a β-globin gene deficiency. Gene repair using homologous recombination in mutant iPSCs made it possible to cure the illness in donor animals. This served as an excellent illustration of an iPSC-mediated regenerative medicine paradigm (Ohnuki and Takahashi, 2015). The easiest method for creating brain organoids with functioning neural networks is to fuse several organoids, such as those of the cortex, thalamus, and other regions, with different identities. Human pluripotent stem cells are used to create brain organoids, which self-assemble to create an organized structure made up of different progenitor, neural, and glial cell types, imitating the layout of the human embryonic brain (Jo et al., 2016; Kadoshima et al., 2013; Lancaster et al., 2017). When attempting to fuse organoids to replicate in vivo brain circuits, there are several factors to consider. The initial step is obtaining locally specified organoids as possible is the initial step. There are two main categories of brain organoid induction techniques. One technique promotes specific separation by adjusting cultural conditions, along with exogenous variables like growth factors or small molecules, while the other takes advantage of the inherent self-patterning characteristics of PSCs (Jo et al., 2016; Kadoshima et al., 2013). Controlling the directionality of connections between organoids is another important consideration. It may be necessary to create a single-directional axon growth between different organoids to replicate in vivo brain circuits. By utilizing the inherent variability of individual organoids, it may be possible not only to connect them but also to produce functioning neural networks within them. The natural self-organizing characteristics of aggregates formed from human pluripotent stem cells are employed in the culturing method developed by Knoblich's group (Lancaster and Knoblich, 2014). Using this method, aggregates are cultured without external stimuli for inductive patterning after being encased in Matrigel. The aggregates' internal signaling and behavior related to autonomous patterns are primarily responsible for their development into brain organoids. The development of polarity or axial data within organoids, and whether it can be controlled, are key questions in the production of arbitrarily designed organoids. The cellular variability of organoids stems, at least in part, from PSCs in a maintenance environment. Although it is generally known that experimental batches of brain organoids created using Knoblich's approach differ in some brain regions, it is unclear what modifications to PSCs during maintenance result in batch effects (Renner et al., 2017). The condition of proliferating cells and undifferentiated PSCs in growing organoids at the individual cell level will be analyzed to determine the causal relationship between heterogeneity in differentiating organoids and cellular states under maintenance settings. Managing the inherent capacity of organoids for self-patterning could benefit from this knowledge (Seto and Eiraku, 2019). Brain organoids derived from pluripotent stem cells are a valuable tool for studying the pathophysiology and growth of human brains because they are capable of imitating normal developmental processes. To a certain extent, the organoids derived from pluripotent adult stem cells, including induced pluripotent stem cells and embryonic stem cells, mimic cell growth and three-dimensional tissue cytoarchitecture in vivo (Camp et al., 2015; Kadoshima et al., 2013).

Consequently, hPSC-derived organoids represent a viable framework for studying both healthy and diseased human developmental processes (Jorfi et al., 2018). It is still difficult to use these organoids to examine the etiology of diseases associated with anomalies in connectivity between distant areas of the cerebral cortex, such as autism spectrum disorders (Dai et al., 2019). Constructing organoids with multiple brain areas and precise connections similar to those found in vivo is crucial in this regard. hiPSCs are readily available sources of stem cells from both healthy individuals and those with brain disorders. As a result, neural cells produced from hiPSCs have been utilized in drug discovery and studies on diseases of the brain, such as studies on Alzheimer's disease, Parkinson’s disease (PD), and autism spectrum. Since many brain disorders have different etiologies and are complicated by varying genetic and epigenetic backgrounds, it is possible to explore the unique pathophysiological characteristics of each disease using patient-derived hiPSCs. An exceptional opportunity to simulate human brain growth and activity is provided by brain organoids, which are commonly unattainable through in-person testing, because they mimic the cellular framework of the human brain as well as its overall tissue organization and growth pattern, unlike traditional 2D cultures of cells (Qian et al., 2019). The hCOs have made it possible to investigate neurological conditions and the early stages of brain growth exclusively (Pașca, 2018; Pașca et al., 2015; Qian et al., 2016). While the development of 3D brain organoids has opened up new possibilities, there are still a number of unanswered questions. These include the absence of functioning blood vessels, the limited development of microglia, and the complexity of different cortical layers (Heide et al., 2018). It is generally accepted that the absence of functioning vasculature impairs the development of neuronal progenitor cells (Shen et al., 2004). The use of brain organoids has advanced the modeling of monogenic diseases in humans (Birey et al., 2017). In addition to complex idiopathic disorders like Autism Spectrum Disorder (ASDs) (Mariani et al., 2015). A notable increase in neural progenitor cell division was observed in brain organoids generated from iPSCs of patients, using an earlier selected endophenotype of ASD patients with macrocephaly (Trujillo and Muotri, 2018). Due to the complexity of the human brain and the restricted access to human brain tissue, it is difficult to understand the neurological causes and mechanisms of many brain illnesses. Our understanding of the effects of genetic alterations and external factors on neural development, neural circuit formation, and function has significantly increased due to studies conducted on model organisms, particularly rats (Leung and Jia, 2016). However, many aspects of human brain development and disorders differ from those observed in rodent systems due to the significant evolutionary distance between the mouse and human brains, as well as the larger size and complexity of the primate brain (Zhao and Bhattacharyya, 2018). hESCs and hiPSCs have the potential to generate a variety of human cell kinds *in vitro*, such as neurons and glia, enabling the direct study of biological processes in a human context. These protocols for the culture and differentiation of hPSCs have made this possible (Avior et al., 2016). Studying the effects of genotypes associated with health and disease on the physiology and development of human cells has been made possible in part by hiPSC technologies. Moreover, summarizing alterations associated with diseases cultured cells and correcting genetic defects in hiPSCs generated from patients have been made easier by genetic modifications using CRISPR-Cas9, TALENs, and zinc finger nucleases. In 2015, Hotta and Yamanaka's methods greatly advanced the study of humans from these methods, neurobiology, revealing cellular characteristics associated with brain diseases.. Sterneckert and colleagues (2014) have shown, however, that monolayered culture methods can only reproduce and study a limited number of disease phenotypes due to the absence of tissue architecture and tissue environment. A new area of study was made possible by the original brain organoid culture methods developed by the Sasai group (Kadoshima et al., 2013; Lancaster et al., 2013; Seto and Eiraku, 2019). Many brain organoid protocols and associated methods, including spheroid protocols (Paşca et al., 2015), have been developed in recent years to replicate certain features of prenatal and embryonic neural growth. The breadth of existing protocols includes the creation of simpler organoids that are targeted at particular brain regions, as well as more complex organoids that replicate connections between cells and interconnectedness among various brain regions.

Brain organoids: a collection of bioassays to study neurodevelopment and illness in humans, and neuroectodermal fate to produce neural tissue. Lancaster et al. developed the brain organoid procedure using sparse media based on this concept. With the help of matrix embedding and hPSC self-organization and self-patterning, this protocol produces neuronal structures made of neuroectodermal tissue. Recapitulating the structure of the brainstem and progenitor cells' germinal zones structure of tissues as the distinct neurons migrate outward. Thus, this procedure can be used to study phenotypes associated with tissue topology. For example, the cerebral organoid procedure was recently used to mimic periventricular heterotopia using hiPSCs from an individual with variations in the FAT4/DCSH1 genes. In examining the effects of the FAT4/DCSH1 variations, the authors discovered a deviation in the radial glia cells, which serves as a support for the cortical neurons' radial migration. Furthermore, the mutant organoids exhibited altered neuronal condition of neurons with differently generated genes linked to movement and guidance of neurons, as demonstrated by RNA sequencing analysis combined with pedigree restoration. The discovery that some neurons in the mutant organoids had abnormal migration patterns supported this finding (Klaus et al., 2019). Differential signaling pathways that are either triggered or suppressed by signaling molecules or morphogens released *in vivo*, which guide the arrangement of cells in specific areas to design the neural tube during development, establishing the identity of distinct brain regions. By including molecules with specific patterns in the culture media that either promote or inhibit signaling for growth at the appropriate stages, one can use these guidelines *in vitro* to control organoids and guide the cells to adopt the fates of specific brain regions. Although these chemical combinations define the general identities of brain regions, it is difficult to create organoids that are specific to individual subregions. For example, the visual cortex, located in the occipital lobe, and the prefrontal cortex, which is located in the frontal region, for example, are two examples of the various functional areas that make up the mammalian cortex. These areas vary in terms of their cellular diversity, gene expression patterns, and functions (Clowry et al., 2018; Molnár et al., 2019). Furthermore, human brain regions, such as the prefrontal cortex, are abnormally large and linked to mental illnesses. Nevertheless, the current cortical organoid methods produce cortical tissues with heterogeneous identities. Innovative techniques that produce organoids of particular cortical regions will be valuable in advancing research on human brain disorders.

Accordingly, it has been demonstrated that applying FGF8, an anterior developmental factor, reaches the cortex organoids causes the cortical tissue to rostralize (Kadoshima et al., 2013). However, since identical signaling molecules are involved in the arrangement of distinct areas of the brain, the present task is to find molecular mixtures characterized by chemical components or corresponding treatment timelines that reliably and economically identify specific brain regions of interest. The brain's intricate circuitry is the result of interactions between cells in various, frequently very distant, brain areas. Two different cellular actions help overcome the issue of selecting the ideal functional partner: As an example, neurons in the cortex migrate forward from the ventral telencephalon into the brain's cortex. First, aggressive cell migration to the desired locations and second, long-term projections; for example, the "thalamocortical tract" relays sensory data from neurons in the cortical and thalamic nuclei (Molnár et al., 2019). Axon pathfinding or neuronal migration defects can cause severe birth defects and cortical abnormalities. Engel (2010) and Ross & Walsh (2001). Nevertheless, region-specific organoids are unable to recreate interregional cell interactions, and the inconsistent cerebral organoid methodology hinders the establishment of consistent areas of expertise connected. To get around this issue, several labs created organoid fusion techniques, in which fresh organoids and prepatterned EB are mixed in a tube or encapsulated in a single Matrigel droplet (Birey et al., 2017). The two regions eventually merge and show intricate cell connections. Studying the impact of genetic background on neuronal behavior, both cell autonomous and nonautonomous, is made possible by the fusion of organoids with disparate genetic origins. Furthermore, viewing of these intricate cellular behaviors, like long-term estimates, axon navigation, and migration of neurons, is made possible by Direct observation of the organotypic segments or merged organoids. Morphogen activity gradients in the AP and DV directions are responsible for the brain's immense neuronal diversity. In 2015, Suzuki and Vanderhaeghen. Any morphogen that is supplied to the media, though, is given in a consistent concentration, which might limit the range of outcomes. Employing a two-stage EB generation procedure, Cederquist et al. devised a unique method for creating organoids with downstream patterning and a gradient of morphogen activity. Originally, transgenic hPSCs that could induce the production of a morphogen were used to create a small EB. A larger EB with an inducible signaling center or organizer was formed by the subsequent seeding of more hPSCs. The released morphogen spread throughout the tissue to form a gradient once morphogen expression was induced. Cederquist et al. produced organoids having telencephalic function and a radially organized DV axis by using this approach to construct a range of the morphogen SHH that induces ventral growth. Cederquist and colleagues, 2019. Microglia and vascular cells are examples of non-neurodermoectodermal origin cells seen in the brain. Macrophages found in the brain, called microglia, are essential for the development and operation of neurons. Neurodegenerative diseases and mental conditions, including autism and schizophrenia, are linked to microglial dysfunction. However, in the current organoid systems, it is challenging to create microglia synchronously with the neuroectoderm, since they originate in the yolk sac. According to a new study, cerebral organoids contain microglial-like cells that arise from a small number of mesodermal cells during the cerebral organoid process. Nevertheless, other researchers have co-cultured organoids with hiPSC-derived microglia, allowing the microglia to penetrate the organoid in order to broaden the application of these brain organoid procedures. Recently, the removal of amyloid β protein clumps containing mutations linked to familial Alzheimer's disease was investigated using this co-culture paradigm. *In vitro* restitution of microglial activities in organoids will be enhanced by further advancements and experiments with these techniques. The migration of cortical interneurons is a particularly illuminating subject for the organoid fusion technique. It is now feasible to observe the distinctive movement of cortical neurons in salt-dependent motion and investigate the effects of both genetic and pharmacological perturbations on these migrant characteristics, thanks to the convergence of ventral and dorsal organoids, or DV mixtures. The effects of mutations in functions causing Timothy syndrome (TS) were investigated by Birey et al. using the DV mixture method. Upon fusing control dorsal telencephalic organoids with ventral organoids cultivated using hiPSCs generated from TS patients, the interneurons harboring the TS mutation displayed abnormalities in saltatory movement that were cell-autonomous. The effects of the alterations were mitigated, and the issues were resolved by using a substance that decreased the calcium channel's function (Birey et al., 2017). Though still in its infancy, the field of brain organoids is growing thanks to the development of improved techniques. Brain organoid techonology possesses the potential to create practical assays for examining additional complicated characteristics when combined with novel experimental techniques.

2. CONCLUSION

This review has highlighted several recent studies that point to potential directions for future research using brain organoids to study brain diseases and functions within the context of neural networks. Brain organoids have emerged as a highly valuable tool for understanding the developmental processes of the human brain and the underlying mechanisms of neurological disorders. Derived from hiPSCs, organoids mimic natural growth mechanisms, providing researchers with the opportunity to study early brain development and pathophysiological processes in a three-dimensional environment. Specific models, such as hCOs, hold significant potential, particularly in understanding the formation and functions of cortical layers.

However, current technologies face several limitations. Recent innovative studies have introduced various strategies to overcome these limitations. Techniques such as microvascularization technologies, advanced bioengineering approaches, and the incorporation of extracellular matrices into the organoid environment aim to enhance the accuracy of these models.

In the future, this technology is expected to pave the way for groundbreaking applications in neurological disorder treatment, early diagnosis, and personalized medicine. Further optimization of brain organoids holds immense potential for both basic science and clinical research. In this context, interdisciplinary collaborations and continuous technological advancements will solidify the role of brain organoids in scientific investigations.

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