Indian Journal of Advances in Chemical Science

Review Article

Evolutionary Changes in the Human Dento-Oro-Maxillofacial System during Martian Residence (Review Article)

Abdollah Ebrahimi[1], Yasmina Nik Hoosh[1], Amir Arab[2], Mehdi Koeini[3], Morteza Davoody Roshan[4]*

[1]Member of Research Committee, Semnan Dental Faculty, Semnan University of Medical Science, Semnan, Iran, [2]Member of Research Committee, Semnan Nursing Faculty, Semnan University of Medical Science, Semnan, Iran, [3]School of Nursing and Midwifery, Student of Semnan University of Medical Science, Semnan, Iran, [4]Member of Research Committee, Semnan Medical Faculty, Semnan University of Medical Science, Semnan, Iran

ABSTRACT

The structure of the human body, including the jaw, oral cavity, and teeth, is constantly evolving throughout its life. It is in the direction of adapting, which is influenced by various environmental factors. Human survival on Mars is critical compared to earth, due to gravity is lower on Mars (3.71 m/s compared to the Earth's 9.81 m^2). Hence, evolution and adaptations in the jaw, oral cavity and teeth problems are highly expected. When the gravitational pressure decreases, the bone density will probably decrease as well, and then, the structure of the jaw and teeth will change. Other causes include a different diet compared to what exists on the Earth, and changes in the gut microbiome (including the oral cavity) are likely to cause greater adaptability. Hence, the diet that is likely to be adopted on Mars has created a more acidic environment in the oral cavity, which causes the teeth of humans living on Mars to decay more and more. The research that was done on animals revealed changes in the density and composition of ivory, which is likely to occur in the same way for humans. It seems that during the years that humans will live on Mars, the structure of their jaws and oral cavity will be constricted and also the number and size of teeth will be decreased. This research states that it is necessary to conduct more studies to better understand the evolutionary effects that are formed on humans living on the planet Mars.

Key words: Adaptation, Evolution, Mars, Oral cavity, Teeth.

1. INTRODUCTION

Humans are always in the process of evolution, and factors such as the type of culture, lifestyle, and environmental conditions cause humans to be in the process of adaptive evolution (adaptation to existing conditions). Among these, we can mention factors such as the achievement and ability of humans in the field of agriculture, which led to population density, which was followed by evolution to deal with diseases, so that the sickle cell allele increased in frequency among Africans [1,2].

Furthermore, when a person acquires a new science or tool or is placed in a situation and environment that is new to him, his physical condition adapts accordingly. For example, when he got a tool to cut food, over time, due to less need to chew and struggle to eat food. In a study, which was conducted on rats, the size of his mouth and dental system became smaller [1].

Now, if we consider that living animals or humans survive on Mars, during the passage of time, changes will occur to their oral and dental system, as follows: the strength of the Earth's gravitational force is equal to about 9.81 m/s^2 [3], and the gravity force on Mars is equal to 3.71 m/s^2 [4]. The impact of this decrease in gravity on the human oral and dental system has caused less pressure on the bones and teeth, which causes a decrease in the density of the bones and subsequently the structure of the jaw, face, and oral cavity. This process over several years causes jaws and teeth to become smaller. Among other changes, there are genetic changes that can take place due to weather conditions and new environments that affect the structure and size of jaws and teeth in humans. A clear example of genetic change in humans is based on environmental conditions. For example, the evolution that occurred in humans living in the Himalayas, in them, due to the lack of iodine in their diet a genetic transformation and evolution has occurred and they have adapted to alternative versions of the thyroid gene (DIO2), which makes their bodies produce and secrete thyroid hormones more efficiently as well as more suitable to their physical conditions. This has prevented the enlargement of the thyroid gland and the problem of goiter [5-8].

1.1. Scientific Analysis

After living and being born on Mars for thousands of years, humans undergo changes and evolution in the oral and dental system that will occur to adapt to the environmental conditions of Mars, which include the following:

a. Researchers have also found that the amount of bone loss in space in the range will be approximately 1–2% of bone density per month, which may vary up to 5–7% (which includes the bones of the oral-jaw region) [9].

***Corresponding author:**
Morteza Davoody Roshan,
E-mail: mory1380khaste@gmail.com

ISSN NO: 2320-0898 (p); 2320-0928 (e)
DOI: 10.22607/IJACS.2024.1203002

Received: 07th April 2024;
Revised: 20th July 2024;
Accepted: 02th August 2024
Published: 05th September 2024

b. There will also be changes in the digestive system (the oral cavity is also a part of the digestive system [10]), so that the diversity in the GIT microbiome decreases, and on the other hand, the abundance of certain types of bacteria is formed, which is generally decreased due to changes in diet. Furthermore, the light conditions that humans are exposed to outside the Earth's atmosphere differ [11].
It should be noted that the human GIT (including the oral cavity) has the most diverse types of microorganisms compared to the rest of the body, and the specific types of microbial mess can cause inflammatory bowel diseases such as Crohn's disease and ulcerative colitis, which can cause oral and dental diseases, including oral ulcers and gingivitis [12].
c. So far, no evidence of animal life has been seen on Mars [13], but researchers did some work on growing plants in an environment simulated on the Moon and Mars, and the plants were able to grow in both situations [14]. Therefore, if Martians use plant resources extensively during their life, due to the creation of more acidic conditions in the oral cavity, they will cause more tooth caries and decay [15].
d. Effect on tooth morphology: Although there is insufficient research on the effect of space atmosphere on dental changes, studies have generally been conducted on animals, and it is possible to generalize animal studies to humans [16,17]. In a research conducted on rats, it was found that traveling to space for a period of 2 weeks caused dentinal effects to their teeth in such a way that their dentin formation showed to be 20% less than what happens in the Earth's atmosphere [16].
e. In another study, which was also conducted on rats, it was found that when they are placed in microgravity for 8 weeks, changes occur in the structure and composition of their dentin, which includes a decrease in the density of the dentin minerals [16].

2. MATERIALS AND METHODS

This research aims to study the evolution of the human oro-dento-maxillofacial system in the Martian environment, which is based on the analysis of the available scientific literature in the following cases:

The effects of microgravity applied on the density and morphology of the jaw, mouth, and teeth: Studies that weaken the bones of astronauts and also investigate the effect of the lack of gravity on bone health were investigated.

Possible change in diet and GIT microbiome: Research that looked at the effects that diet can have on oral health and could change the GIT microbiome due to the diet of humans who are likely to live on Mars.

Animal studies in atmospheric conditions simulated with the atmosphere of Mars: Studies that investigated the effects of microgravity on the morphology of teeth in animal species were analyzed to infer human technologies.

The review process includes the following:

1. Literature search: PubMed database was searched using relevant keywords, such as Mars, microgravity, oral cavity, teeth, and bone density. Regarding the gut microbiome, the keywords of evolution and adaptation were also searched.
2. Inclusion and exclusion criteria: Studies published in research databases that focus on the effects of gravity reduction or environmental changes on the structure of the jaw, oral cavity, and teeth. It should be noted that studies that were based solely on terrestrial conditions or had no clear connection with the atmospheric conditions of Mars and were excluded.
3. Data extraction and analysis: Extracted data included findings regarding changes in bone density, likely dietary changes, microbiome changes in GIT, and proven effects on tooth morphology (in animal models). The data were analyzed to understand the evolution and to be able to extrapolate it to the evolution that humans will have on Mars.

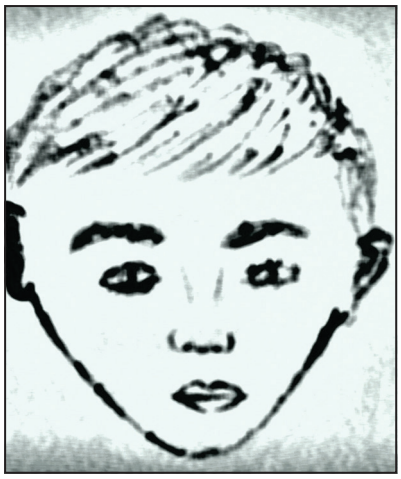

Figure 1: Anterior view.

Figure 2: Lateral view.q

Figure 3: Lateral view (dentoskeletal).

2.1. Current Limitations of the Study

More research is needed to be done specifically on the dental system, the oral cavity, and the human jaw in the conditions of Mars to bring more understanding to humankind. However, it should be noted that the course of evolution in the long term (for example, thousands or even millions of years) challenges all these predictions.

3. RESULTS

This research shows that humans may experience changes in their oral and dental systems when they are exposed to the atmospheric conditions of Mars. The reduction of gravity, changes in diet, and also various environmental factors can affect the physiology of the human body, which we will discuss below:

1. Bone density and structural changes:
   Research results show that in a microgravity environment similar to Mars (with a gravitational force of 3.71 m/s compared to 9.81 m/s on the Earth), a significant decrease in human bone density occurs. Studies say that the monthly decrease in bone density is approximately 1–2%, which can increase to 5–7% in some cases.
   This can affect the jaw and facial region, and lead to a smaller jaw size, as well as weaken dental structures over several years [Figures 1-3] [18].
   From the point of view of evolution, changes are usually formed over thousands or millions of years, which means that environmental changes cause selective pressure on a population and cause adaptations to be formed in line with the survival of the generation [19]. However, according to the aforementioned findings, if humans are exposed to microgravity, they adapt to less bone density and smaller jaws, as mentioned in the above text, and it has already been noted that evolution requires thousands and even millions of years in many cases [19-21].
2. Changes in the digestive system and microbiome:
   Since the food habits and also the changes in the light conditions that humans are exposed to that on the planet Mars, the digestive system, including the oral cavity, faces changes that are significant in turn. It is expected that the diversity in the GIT microbiome will decrease, which can endanger those organ's health [22]. It can be said that inflammatory bowel diseases such as Crohn's disease and ulcerative colitis, whose oral manifestations are ulcers and gingivitis, are among them.
   Therefore, with relatively high confidence, in terms of the changes in dental development, it can be said that it is because of the changes that are formed due to the diet that is more toward vegetarianism. Furthermore, the use of soft food, as well as microbial changes, will lead to tooth decay. Hence probably the size of the teeth becomes smaller over the years, and their hard tissue structure becomes thinner due to the decrease in the amount of minerals [23-25].
3. Dental changes in terms of morphology:
   Animals were able to increase human knowledge about possible changes in extraterrestrial atmospheric conditions based on changes in tooth morphology. When the mice were placed in microgravity, their dentin was significantly affected and became less dense, meaning that dentin production decreased by about 20% over a 2-week period. When this time period increases to 8 weeks, changes in the composition of the dentin will also occur. According to the mentioned reasons, it is expected that the condition of the teeth is adapted to human survival during the evolution process, including changes in shape and size, as well as a reduction in their size and number (this is a hypothesis according to the general findings of this study) [26,27].
4. Genetic adaptability:
   Human adaptation to the environment generally occurs with genetic changes, a clear example of which was the adaptation of the Himalayan people to a low-iodine diet, which was associated with changes in the thyroid hormone-producing gene (DIO2). This shows that genetic transformation and evolution occur in line with the adaptability of humans to the environment. Therefore, it

Section	Title	Content
Abstract	The evolutionary effect of Martian life on a human oro-dento-maxillofacial system	Studying the effect of reduced gravity on the oro-dento-maxillofacial region and system of humans during their prolonged residence on Mars
Keywords	Evolution, Mars, Adaptation, Oral cavity, Teeth	
Introduction	The process of human evolution	Researching the process of human evolution (in the long-term life) on Mars, with regard to the environmental effects, as well as a prospective look at their future generations
Scientific analysis	Transformation and evolution caused by living on Mars	Research on possible changes in the human oro-dento-maxillofacial system due to gravity reduction, modified diet (which causes acidic and bacterial modification in the GIT)
Materials and methods	Research methodology	Description of the research method based on the analysis of scientific articles
Current limitations of the study	Need of more research	Addressing that further research is needed to more fully understand the impact of the Martian environment on humans
Results	Possible evolutionary effects of habitation on Mars	Research on scientific findings about the effect of reduced gravity, modified diet, etc., on the human oro-dento-maxillofacial structures and system
Discussion	Human adaptation to the Martian environment	Analyzing the scientific findings, and making out conclusions about the compatibility of the human oro-dento-maxillofacial system with the environment of Mars
Conclusion	Emphasizing the need of more research	Pointing out the need for more research to better understand the process of human evolution on Mars
References		The list of material sources (all of which are articles) mentioned in this research

can be expected that genetic changes will be formed in humans who will live on Mars.

4. DISCUSSION

1. Man is an adaptable creature, and the oro-dento-maxillofacial system undergoes evolution based on local and atmospheric conditions. The gravitational force of the Mars sphere is less than that of the Earth, and this affects the bone density and reduces it, as a result of which structural changes are formed in the jaw, face, and teeth [28-30].
2. The dietary habit that changes in humans causes physiological changes, for example, when a person turns to vegetarianism, his oral cavity becomes more acidic, which can cause more tooth decay. As mentioned, there is no evidence of the existence of humans on Mars, but there is evidence of the possibility of the growth of plant species there, so the adoption of a vegetarian style by the Martians is high, and the consequences mentioned will probably include their condition [31-33].
3. The changes that occur in the GIT microbiome also create an important dimension, such that a decrease in the diversity and saturation of microbes creates the potential for certain bacteria to grow there, which can cause harm to the oral cavity [22,34,35].
4. Another matter is genetic adaptability. As per a study on mice in microgravity conditions to understand its effects on the evolution of tooth morphology, researchers absorbed a reduction in the formation of dentin and also changes in tooth composition [5-8,26,27].

5. CONCLUSION

The anticipated alterations in the Martian atmosphere over thousands, and potentially millions, of years are expected to significantly impact the interaction between the human theredo-dento-maxillofacial systems and the environmental and atmospheric conditions on Mars. Based on the results of this study, it is evident that further extensive research is required to gain a complete understanding of these adaptations. When humans inhabit Mars, a planet with lower gravity than Earth, their diet and gastrointestinal microbiome undergo changes. These changes lead to physical and genetic adaptations to the Martian conditions, resulting in weakened teeth and a decrease in their number. Additionally, the size of oro-dento-maxillofacial structures is reduced.

6. REFERENCES

1. A. R. Templeton, (2010) Has human evolution stopped? ***Rambam Maimonides Medical Journal***, **1(1)**: e0006.
2. S. D. Grosse, I. Odame, H. K. Atrash, D. D. Amendah, F. B. Piel, T. N. Williams, (2011) Sickle cell disease in Africa: A neglected cause of early childhood mortality, ***American Journal of Preventive Medicine***, **41(6 Suppl 4)**: S398-S405.
3. M. Gallagher, A. Torok, J. Klaas, E. R. Ferrè, (2020) Gravity prior in human behaviour: A perceptual or semantic phenomenon? ***Experimental Brain Research***, **238(9)**: 1957-1962.
4. A. Torok, M. Gallagher, C. Lasbareilles, E. R. Ferrè, (2019) Getting ready for Mars: How the brain perceives new simulated gravitational environments, ***The Quarterly Journal of Experimental Psychology*** (***Hove***), **72(9)**: 2342-2349.
5. P. Rybarczyk, A. Vanlaeys, B. Brassart, I. Dhennin-Duthille, D. Chatelain, H. Sevestre, H. Ouadid-Ahidouch, M. Gautier, (2017) The transient receptor potential melastatin 7 channel regulates pancreatic cancer cell invasion through the Hsp90α/uPA/MMP2 pathway, ***Neoplasia***, **19(4)**: 288-300.
6. M. C. H. Tointon, (2019) Approximate subgroups of residually nilpotent groups, ***Mathematische Annalen***, **374(1)**: 499-515.
7. A. Garg, A. Saini, (2016) Effect of microgravity on oral cavity: A review, ***IOSR Journal of Dental and Medical Sciences***, **15(1)**: 91-94.
8. G. H. Sperber, (2013) The role of teeth in human evolution, ***British Dental Journal***, **215:** 295-297.
9. J. Man, T. Graham, G. Squires-Donelly, A. L. Laslett, (2022) The effects of microgravity on bone structure and function, ***NPJ Microgravity***, **8(1)**: 9.
10. J. J. Patricia, A. S. Dhamoon, (2024) Physiology, digestion. In: StatPearls. Treasure Island, FL: StatPearls Publishing. Available from: https://www.ncbi.nlm.nih.gov/books/NBK544242 [Last accessed on 2022 Sep 12].
11. H. S. Dong, P. Chen, Y. B. Yu, P. Zang, Z. Wei, (2019) Simulated manned Mars exploration: Effects of dietary and diurnal cycle variations on the gut microbiome of crew members in a controlled ecological life support system, ***PeerJ***, **7**: e7762.
12. S. Kitamoto, H. Nagao-Kitamoto, R. Hein, T. M. Schmidt, N. Kamada, (2020) The bacterial connection between the oral cavity and the gut diseases, ***Journal of Dental Research***, **99(9)**: 1021-1029.
13. C. P. McKay, (1997) The search for life on Mars, ***Origins of Life and Evolution of Biospheres***, **27(1-3)**: 263-89.
14. G. W. W. Wamelink, J. Y. Frissel, W. H. J. Krijnen, M. R. Verwoert, P. W. Goedhart, (2014) Can plants grow on Mars and the moon: A growth experiment on Mars and moon soil simulants, ***PLoS One***, **9(8)**: e103138.
15. B. Shkembi, T. Huppertz, (2023) Impact of dairy products and plant-based alternatives on dental health: Food matrix effects, ***Nutrients***, **15(6)**: 1469.
16. M. S. Moussa, M. Goldsmith, S. V. Komarova, (2023) Craniofacial bones and teeth in spacefarers: Systematic review and meta-analysis, ***JDR Clinical and Translational Research***, **8(2)**: 113-122.
17. M. B. Bracken (2009) Why animal studies are often poor predictors of human reactions to exposure, ***Journal of the Royal Society of Medicine***, **102(3)**: 120-102.
18. S. Kahn, P. Ehrlich, M. Feldman, R. Sapolsky, S. Wong, (2020) The jaw epidemic: Recognition, origins, cures, and prevention, ***Bioscience***, **70(9)**: 759-771.
19. A. Rinaldi, (2017).We're on a road to nowhere: Culture and adaptation to the environment are driving human evolution, but the destination of this journey is unpredictable, ***EMBO Reports***, **18(12)**: 2094-2100.
20. I. R. Cohen, A. Marron, (2020) The evolution of universal adaptations of life is driven by universal properties of matter: Energy, entropy, and interaction, ***F1000Res***, **9:** 626.
21. A. P. Hendry, M. T. Kinnison, M. Heino, T. Day, T. B. Smith, G. Fitt, C. T. Bergstrom, J. Oakeshott, P. S. Jørgensen, M. P. Zalucki, G. Gilchrist, S. Southerton, A. Sih, S. Strauss, R. F. Denison, S. P. Carroll, (2011) Evolutionary principles and their practical application, ***Evolutionary Applications***, **4(2)**: 159-183.
22. A. Sadeghi, A. Sarrafan, A. Ebrahimi, N. Moghadamnia, P. M. Semnani, S. A. R. Tekieh, A. Modarresi, (2023) The effect of dental prosthesis on oral normal microbes and life span, ***Clinical Cancer Investigation Journal***, **12(1)**: 1-6.
23. G. A. Scardina, P. Messina, (2012) Good oral health and diet, ***Journal of Biotechnology and Biomedicine***, **2012:** 720692.
24. L. Santacroce, P. C. Passarelli, D. Azzolino, L. Bottalico,

I. A. Charitos, A. P. Cazzolla, M. Colella, S. Topi, F. G. Godoy, A. D'Addona, (2023) Oral microbiota in human health and disease: A perspective, ***Experimental Biology and Medicine*** (***Maywood***), **248(15)**: 1288-1301.
25. I. Olsen, K. Yamazaki, (2019) Can oral bacteria affect the microbiome of the gut? ***Journal of Oral Microbiology***, **11(1)**: 1586422.
26. C. N. Q. Ho, M. T. Tran, C. C. Doan, S. N. Hoang, D. H. Tran, L. T. Le, (2021) Simulated microgravity inhibits the proliferation of chang liver cells by attenuation of the major cell cycle regulators and cytoskeletal proteins, ***International Journal of Molecular Sciences***, **22(9)**: 4550.
27. S. McKinley, A. Taylor, C. Peeples, M. Jacob, G. Khaparde, Y. Walter, A. Ekpenyong, (2023) Simulated microgravity-induced changes to drug response in cancer cells quantified using fluorescence morphometry, ***Life*** (***Basel***), **13(8)**: 1683.
28. O. J. Juhl 4th, E. G. Buettmann, M. A. Friedman, R. C. DeNapoli, G. A. Hoppock, H. J. Donahue, (2021) Update on the effects of microgravity on the musculoskeletal system, ***NPJ Microgravity***, **7(1)**: 28.
29. S. N. Sisli, E. Gul-Ates, T. B. Ozcelik, B. Yilmaz, M. Revilla-León, (2023) Survival of root canal-treated teeth adjacent to an implant: A retrospective case-control study, ***Journal of Dentistry***, **139:** 104742.
30. H. J. Zhao, Y. P. Pan, (2023) Characteristics of alveolar bone loss in severe periodontitis and consideration of rehabilitation with implant, ***Zhonghua Kou Qiang Yi Xue Za Zhi***, **58(3)**: 298-304. [Chinese]
31. O. I. Osman, (2014) Experimental and theoretical investigation of the pyrolysis products of iminodiacetonitrile, (N≡CCH2)2NH, ***The Journal of Physical Chemistry A***, **118(46)**: 10934-10943.
32. J. F. Edwards, S. E. Wikse, J. K. Loy, R. W. Field, (1995) Vertebral fracture associated with trauma during movement and restraint of cattle, ***Journal of the American Veterinary Medical Association***, **207(7)**: 934-935.
33. M. Nguyen-Nielsen, M. Nørgaard, J. B. Jacobsen, M. Borre, R. W. Thomsen, M. Søgaard, (2013) Comorbidity and survival of Danish prostate cancer patients from 2000-2011: A population-based cohort study, ***Clinical Epidemiology***, **5(Suppl 1)**: 47-55.
34. A. R. Moorey, A. Cabanillas, S. M. Batt, S. Ghidelli-Disse, B. Urones, O. Sanz, J. Lelievre, M. Bantscheff, L. R. Cox, G. S. Besra, (2021) The multi-target aspect of an MmpL3 inhibitor: The BM212 series of compounds bind EthR2, a transcriptional regulator of ethionamide activation, ***The Cell Surface***, **7:** 100068.
35. G. K. Simsek, H. G. K. Kutman, F. E. Canpolat, (2020) The effects of antenatal steroid treatment on preterm infants' early laboratory analysis, ***Sisli Etfal Hastanesi Tip Bulteni***, **54(4)**: 433-437.

****Bibliographical Sketch***

Abdollah Ebrahimi is a Member of Research Committee, Semnan Dental Faculty, Semnan University of Medical Science, Semnan, Iran.

Email: ebrahimi56666@gmail.co