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Evaluation of the physical properties of a novel twin block appliance in treatment of skeletal class II growing females with mandibular deficiency

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***Abstract*---**Objective: This study was performed to reveal the physical changes of polymers used after gamma irradiation of a modified twin block appliance versus conventional twin block appliance in the treatment of growing females with skeletal Class II malocclusion having mandibular deficiency. Materials and methods: The total sample consisted of 12 specimens 6 from every polymer, modified twin block group which was composed of polyethylene polymer and conventional twin block group which was formed of poly methyl-methacrylate polymer used in this study, exposed to different gamma irradiation doses (25 KGray and 30 KGray) in order to test their physical properties.

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Assessment was done using UV-visible spectroscopy and scanning electron microscope. Results: This study revealed that concerning the gamma radiation effect on the polymers used, Poly methyl methacrylate showed yellowish color change and increased number of pores on its surface after irradiation while polyethylene vacuum sheets didn't show any color change but the scratches and pores appeared on its surface using scanning electron microscope. Conclusion: From the previous results it can be concluded that the modified twin block appliance can be used as an alternative orthopedic appliance in treatment of skeletal class II malocclusion growing subjects with mandibular retrusion. No change in physical properties has occurred for the thermoplastic sheets post irradiation but yellowish discoloration occurred for cold cured acrylic resin.

***Keywords*---**twin block appliance, polymers, physical properties, gamma irradiation.

Introduction

Skeletal Class II malocclusion is one of the most common problems encountered in orthodontics around the world. During the permanent dentition stage, the percentage represents 19.56 percent of all forms of malocclusions, while the percentage in the mixed dentition is even higher globally.[1,2]

The oral cavity is a dynamic environment, many components affect the service and durability of different materials as in the oral cavity polymers as composites are subjected to numerous destructive influences. Appliances had been proved to accumulate minute food debris and remnants on their surfaces after their usage in the oral environment. This has been attributed to the number of pores present under magnified scanning which in return affects the material's strength.

For patients in their adolescent growth spurt, functional appliances are used to resolve skeletal class II situations, which has always been a struggle for orthodontists. Functional appliances needs to stay in the patient's mouth for long hours every day to produce their effect to help patients establish appropriate mouth and tongue posture along with minimizing overjet.[3.4]

These devices do have some drawbacks, the most important of which is demonstrating adherence to therapy. Perfect compliance is required to achieve the results shown in the research, which unfortunately cannot be guaranteed in orthodontic practice. The negatives are linked to the weight of the appliance, as well as the aesthetics and speech issues that come with wearing it. Condylar positive development was also seen in the mandibular pre-pubertal female assessment.[5]

Polymers used in the biomedical sector can be exposed to ionizing radiation (in vivo as implants or ex vivo for sterilization purposes or to improve their physical properties). However, this ionizing radiation can cause degradation or improvement of the polymer. Studies have described their physical properties, such as transparency, surface changes flexibility, conductivity, and resistance to different environmental conditions, and many different physical properties are required for the scientific applications of these polymers. They can be improved on the basis of their physical properties to eliminate their disadvantages.[6,7]

This study was performed to assess the change in physical properties of polymers used as a result of gamma irradiation.

Materials and methods:

Registration:
This trial was registered at the Clinical Trails.gov registry under registration number
NCT03635463 on August 4th 2018.

Study design:
This study was designed as an in vitro study.

Sample size estimation:

We were planning a study of a 12 experimental specimens measured before and after irradiation as before irradiation acted as a control to be able to reject the null hypothesis that the population means of the experimental and control groups are equal with probability (power) 0.8. The Type I error probability associated with this test of this null hypothesis is 0.05. Calculations were made using PS Power and Sample Size Calculations, Version 3.0.
(http://biostat.mc.vanderbilt.edu/PowerSampleSize)

Grouping: The polymer groups were divided into 6 specimens from each polymer which were further divided into 2 subgroups:
Group A : 3 specimens from each polymer were subjected to 25 KGy dose once.
Group B : 3 specimens from each polymer were subjected to 30 KGy dose once (Fig 1).

The irradiation was performed at National Centre of Radiation Research and Technology(NCRRT), Cairo, Egypt, using radioactive cobalt-60 giving a dose rate of 0.912 Gray/minute at the time of radiation exposure. Each sub-group was placed in a sealed envelope, placed in a plastic wrapping before gamma irradiation exposure.
The analysis methods for the specimens used before and after gamma irradiation:

1. Ultra violet-visible spectroscopy: This test was done to compare the color changes before and after irradiation.
2 Scanning electron microscope: This type of scanning was done to assess surface changes before and after irradiation exposure. The specimens were covered with a fine layer of gold using carbon ribbon as support.

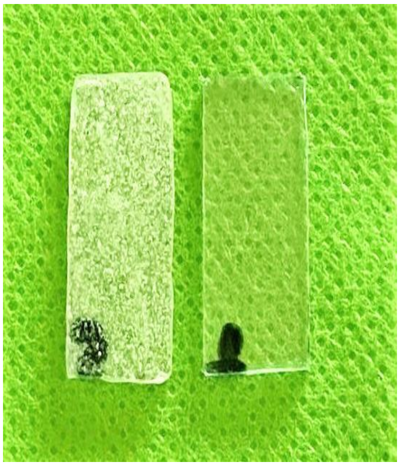

Fig (1): Specimens prepared from both groups (2cmx1cmx1.5cm)

Fig (2): Zeiss scanning electron microscope.

Statistical analysis:

The data distribution was checked for normality, the mean and median values were calculated, and the Shapiro-Wilk test was used. Data had a parametric distribution, thus mean and standard deviation (SD) values were used to depict them. The intra-class correlation coefficient was used to determine inter-observer reliability (ICC). Independent and paired t-tests were used to compare intergroup and intragroup differences. In all tests, the significance level was set to p0.05. R statistical analysis software version 4.1.1 for Windows was used for the statistical analysis.

Results

After completion of treatment and collection of the data pre and post treatment.

These data were divided into twin block material related data that assess the significance of the difference in gamma radiation exposure between the conventional and the modified twin block groups. And the scanning electron microscope to highlight the changes after irradiation for both materials.

The 12 specimens were divided into two equal groups according to gamma radiation exposure. The first group (6 specimens) was subjected to 25 KGray dose once and the second group (6 specimens) was subjected to 30 KGray dose once.

UV-visible spectroscopy:

Significance of the difference in gamma radiation exposure between the conventional and the modified twin block groups: UV Visible spectroscopy has been proven to be a very prominent tool for the study of optical absorption edge in the UV Visible regime. Furthermore, it helps in the determination of indirect and direct transition energy occurring in the ultraviolet band by optical absorption spectra at the fundamental absorption edge of the material.

UV–Visible spectroscopy was performed in the wavelength range 300–800 nm at room temperatureon the pre radiated and irradiated samples.
All samples were irradiated with a Cobalt-60 primary source for gamma radiation, the doses were 25 and 30 KGray, at a dose rate of 0.912 KGray/hour. The total time for 25KGray exposure is 30.3 hours. While the total time for 30 KGray exposure is 36.3 hours. Mean and standard deviation values for irradiation for both groups were presented in tables from (1-3).

For both doses, cold cured acrylic resin (PMMA) had a significantly higher value than thermoplastic vacuum sheets ($p<0.001$). The absorption peak shifts from UV towards the visible region which indicates an increase in the absorption levels after irradiation (Fig 5). For cold cured acrylic resin, value increased significantly after irradiation regardless of the dosage ($p<0.001$). For Vacuum thermoplastic sheets, there was no significant difference between values measured before and after irradiation ($p>0.05$).

Table 1
Comparison of Mean, Standard deviation (SD) of UV absorbance values of difference in radiation.

Dose	Difference in irradiation (Mean±SD)		p-value
	Conventional twin block(PMMA)	Modified twin block (vacuum sheets)	
25KGy	1.32±0.86	0.05±0.18	<0.001*
30KGy	1.66±0.89	-0.07±0.15	<0.001*

*; significant ($p \le 0.05$)

Table 2
Mean, Standard deviation (SD) of UV absorbance values of irradiation (25KGy)

Group	Difference in irradiation (Mean±SD)		p-value
	Before	25KGy	
Cold cured acrylic resin	1.43±0.44	2.75±1.22	<0.001*
Vacuum thermoplastic sheets	1.19±1.47	1.24±1.49	0.941

*; significant ($p \leq 0.05$)

Table 3
Mean, Standard deviation (SD) of UV absorbance values of irradiation (30KGy)

Group	Difference in irradiation (Mean±SD)		**p-value**
	Before	**30KGy**	
Cold cured acrylic resin	1.43±0.44	3.09±1.21	<0.001*
Vacuum thermoplastic sheets	1.19±1.47	1.12±1.51	0.918

*; significant ($p \leq 0.05$)

Scanning electron microscope (SEM):

The scanning electron microscope (SEM) images were used to study the morphological characteristics of PMMA and Polyethylene vacuum sheets before and after irradiation.

Pre irradiated SEM images of poly methyl methacrylate (PMMA) specimens at 100 times magnification revealed pores of evaporated monomer after polymerization. However after irradiation (30KGray) the number of pores increased and more monomer has evaporated. Figure (3,4)

Pre irradiated SEM images of polyethylene polymer specimens at 100 times magnification revealed smooth surface with no voids or pores. Figure (5,6)
Irradiated polyethylene polymer after gamma irradiation showed minute scratches and a pore as aresult of irradiation (30 KGray).

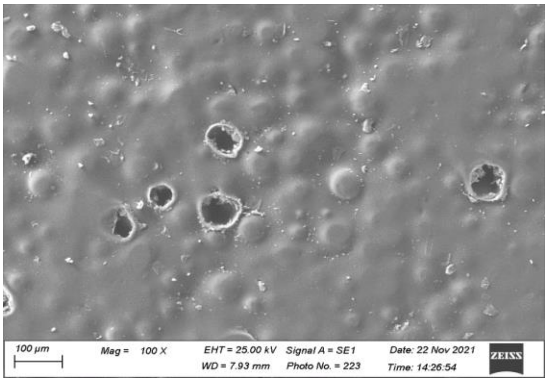

Fig (3): SEM image of PMMA polymer before irradiation.

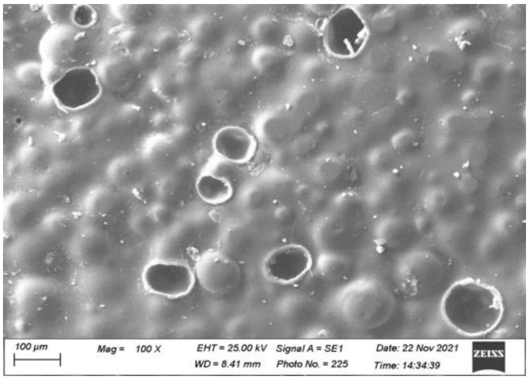

Fig (4): SEM image of PMMA polymer after irradiation.

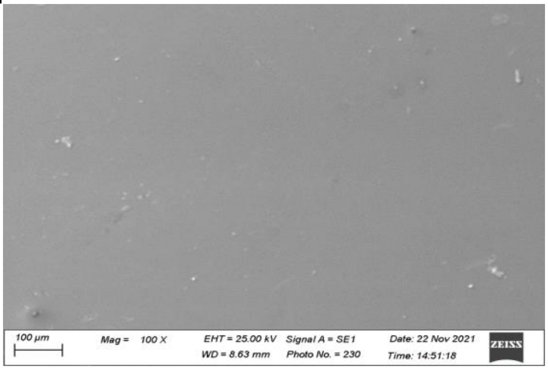

Fig (5) SEM image of Polyethylene polymer before irradiation.

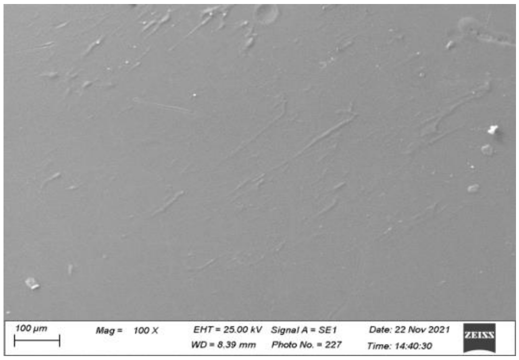

Fig (6) SEM image of Polyethylene polymer after irradiation.

Discussion

During the development of occlusion, jaw discrepancies play a critical role in the development of skeletal Class II malocclusion. The majority of those instances had a component of mandibular deficit, according to several investigations. Many researchers used functional appliances to stimulate mandibular growth by trying to shift the mandible forward and retaining it in that position for an extended amount of time, which can cause bone remodeling and stimulate mandibular base growth, resulting in the correction of the mandibular skeletal discrepancy.[3,4,7,22,31,33]

Removable functional appliances such as the activator, bionator, Frankel, Herbst, twin block, and fixed functional appliances such as Herbst, Jasper jumper, Forsus, twin force, and others are used to treat skeletal Class II malocclusion. The location of the condyle in the glenoid fossa in a more forward position encourages growth in the condylar region. Several studies have compared the use of various functional appliances, and the utility of a twin block appliance in the treatment of skeletal Class II malocclusion has been highlighted. .[5,6,9,13,16,18,19] This was confirmed in a study by Illing et al.[32], who found that the twin block appliance was the most effective in causing sagittal and vertical treatment alterations during growth. Removable functional appliances, on the other hand, have always had the disadvantage of requiring patient cooperation to get beneficial results.

The Twin Block (TB) functional appliance has acquired widespread acceptance among practitioners for the treatment of skeletal Class II malocclusions since its development by Clark. Upper and lower acrylic plates with interlocking bite-blocks were used to generate a favorable forward mandibular displacement when the appliance was sealed. Treatment occurred in the early permanent dentition, however, because the eruption of premolars was required to maintain the traditional twin block in the patient's mouth.

It is widely known that when polymers are exposed to irradiation, they undergo structural alterations. Irradiation of polymers produces free radicals and ions, as well as the formation, tailoring, or rupture of molecular bands. When a polymer is exposed to irradiation, two distinct processes might occur: crosslinking and oxidative breakdown. In general, the dominance of one of these competing processes is influenced by a number of factors, including polymer structure and irradiation settings radiation dose, dose rate, sample thickness, irradiation temperature, etc. [64,65]
The goal of this study was to assess the impact of gamma irradiation on the physical properties of the material used in the production of both types of twin block appliances.

The sample of this study included 12 specimens , 6 from each polymer which were subjected to two different gamma radiation doses half of the specimens (3 specimens from each polymers) were subjected to 25 KGray dose once while the other half was subjected to 30 KGray. These doses were chosen as the stated doses for sterilization of other appliances.
A new modification of the twin block was designed by El kattan [43] to overcome the limitations of the twin block appliance in terms of treatment timing and patient’s compliance the acrylic base and metal clasps were replaced with a thermoplastic layer.

The twin block materials were assessed their physical behavior after gamma irradiation. Two doses were given to specimens and UV visible test was made to accurately compare the amount of light absorbed after irradiation. For both dosages (25 KGray and 30 KGray respectively), cold cured acrylic resin (PMMA) had a significantly higher value than polyethylene thermoplastic vacuum sheets ($p<0.001$). For cold cured acrylic resin, value increased significantly after irradiation regardless of the doses ($p<0.001$). For Vacuum thermoplastic sheets, there was no significant difference between values measured before and after irradiation ($p>0.05$). This occurred as a result of oxidation process and release of oxygen that breaks the polymer chains and changes their color, this is seen intensely as the color turns yellow in PMMA post irradiation. This yellow color was found to be clinically inacceptable. This result was in agreement with Oral et al.[67] Murray et al.[71] and Behr et al.[70]

Scanning electron microscope of poly methyl methacrylate polymer (PMMA) revealed increased number of pores and bubbles due to vaporization of monomer during gamma irradiation, while there was minute scratches and appearance of pores on the surface of polyethylene thermoplastic vacuum sheets after irradiation which will increase amount of minute food impaction within the appliances surfaces and affect its mechanical strength of the long term use. This result has agreed with Ferreira et al. [73] who has stated that the main change in this type of polymer was the appearance of new crystalline domain post irradiation.

Conclusion

The collected data were statistically analyzed for descriptive statistics, treatment skeletal and dental changes, soft tissue changes and comparison between both intervention groups. From the previous results the following conclusions could be drawn:

1. No color change has occurred for the thermoplastic sheets post irradiation as it withstanded the radiation doses assigned for this study but yellowish discoloration occurred for cold cured acrylic resin (PMMA).
2. SEM images revealed surface changes in poly methyl methacrylate (PMMA) and polyethylene vacuum sheets after subjection to gamma irradiation that affects its mechanical strength.

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Regulatory Statement:
All provisions of the local human subjects' oversight committee rules and policies of the ethics committee of scientific research- Faculty of Dentistry- Cairo University- Egypt were followed in the conduct of this study. The approval code for this study is 181031.

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Ethical consideration and approval**:**
This study was conducted in the orthodontic Department - Faculty of Dentistry-Cairo University- Egypt and in the labs National Center For Radiation Research and Technology, Egyptian Atomic Energy Authority, Cairo, Egypt. The ethical approval was obtained from the ethics committee of scientific research Faculty of Dentistry- Cairo University- Egypt (approval no 181031).

Conflict of Interest:
The authors have no financial, proprietary, or other personal interests in any of the products, services, or companies mentioned in this article.

References

1. Alhammadi MS, Halboub E, Fayed MS, Labib A, El-Saaidi C. Global distribution of malocclusion traits: A systematic review. Dental Press J Orthod. 2018;23(6):40.e1–40.e10.doi:10.1590/2177-6709.23.6.40.e1-10.onl
2. Moyers RE, Riolo ML, Guire KE, Wainright RL, Bookstein FL. Differential diagnosis ofclass II malocclusions : part1-facial types associated with class II malocclsuions. Am. J. orthodont. 1980: 78:477-494.
3. El-mangoury NH. skeletal component of angle class II malocclusion. Egy orthod. J. 1990;vol4. No1:57-67
4. Clark WJ. Twin block functional therapy applications in dentofacial prthopedics 2nd edition,mosby-wolf, 2002.
5. Cozza P, Baccetti T, Franchi L, De Toffol L, McNamara Jr JA. Mandibular changes produced by functional appliances in Class two malocclusion: a systematic review. Am J Orthod Dentofacial Orthop 2006;129:599.e1e599.e12.
6. Singh D. and Clark. Localization of mandibular changes in patients with Class II Division 1 malocclusions treated with Twin-block appliances: Finite element scaling analysis. Am J of Orthod and Dentofacial Orthop April 2001;119:4
7. Proffit WR., Phillips C., Tulloch JF., Medland PH. Surgical versus orthodontic correction of skeletal Class II malocclusion in adolescents: effects and indications. Int J Adult Orthodon Orthognath Surg. 1992;7(4):209-20.
8. Wong R.B., Alkhalil A.M., and Rabie A.B. M. Use of cervical vertebral maturation to determine skeletal age. Am. J. of Orthod 2009 0ct:484e1-e6
9. Varlik SK, Gultan A, Nazli Tumer N. Comparison of the effects of twin block and activator treatment on the soft tissue profile. Eur J Orthod 2008;30:128–34
10. O'Brien K, Wright J, Conboy F, et al. Early treatment for Class II Division 1malocclusion with the Twin-block appliance: a multi-center, randomized, controlled trial. Am J Orthod Dentofacial Orthop 2009;135:573 e9.
11. Mark J.E, Physical Properties of Polymers Handbook, 2nd ed. (Springer, New York, 2007.
12. Navarro, R., Burillo, G., Adem, E., & Marcos-Fernández, A. Effect of Ionizing Radiation on the Chemical Structure and the Physical Properties of Polycaprolactones of Different Molecular Weight. Polymers. 2018:10(4):397.
13. Henry RG: a classification of class II,division 1 malocclusion. Angle orthod. 1957: 27:83- 92.
14. Mcnamara, J. A. 'Components of Class II Malocclusion in Children 8–10 Years of Age', The Angle Orthodontist. Edward H. Angle Society of Orthodontists, 1981: 51(3): 177– 202.
15. Karlsen A.T. Craniofacial morphology in children with Angle Class II-1 malocclusion withand without deepbite. Angle Orthod 1994;64(6):437-46.
16. Pancherz H., Zieber K., Hoyer B. Cephalometric characteristics of Class II division 1 and Class II division 2 malocclusions: a comparative study in children. Angle Orthod. 1997;67(2):111-20.
17. Ceylan I., Eroz U. B. The Effects of Overbite on the Maxillary and Mandibular

Morphology. Angle Orthod 2001;71:110–115.
18. Ul-hamid W., Asad S. prevalence of skeletal components of malocclusion using compositecephalometric analysis. pakistan oral & dent. J. 2003: 23 (2).
19. Bishara SE. Class II Malocclusions: Diagnostic and Clinical Considerations With andWithout Treatment. Semin Orthod 2006;12:11-24.
20. Sidlauskas A, Svalkauskiene V, Sidlauskas M. Assessment of skeletal and dental pattern of Class II division 1 malocclusion with relevance to clinical practice. Stomatologija. 2006;8(1):3-8.
21. Isik F, Nalbantgil D, Sayinsu K, Arun T. A comparative study of cephalometric and arch width characteristics of Class II division 1 and division 2 malocclusions. Eur J Orthod. 2006 Apr;28(2):179-83.
22. Gul E., Fida M. Pattern of malocclusion in orthodontic patients: a hospital based study.JAMC Jan-Mar 2008;20(1):43-7.
23. Al-Khateeb EA, Al-Khateeb SN. Anteroposterior and vertical components of class II division 1 and division 2 malocclusion. Angle Orthod. 2009 Sep;79(5):859-66.
24. Oshagh M., Ghaderi,F., Pakshir,H.R. & Baghmollai,A.M. Prevalence of malocclusions in school-age children attending the orthodontics department of ShirazUniversity of Medical Sciences. EMHJ, 2010: 16 (12), 1245-1250.
25. Al-hammadi MS. The prevalence of malocclusion in a group of Yemeni adult population: an epidemiologic study. MSc thesis, department of orthodontics, cairo university;2010.
26. Aldrees AM. Pattern of skeletal and dental malocclusions in Saudi orthodontic patients.Saudi Med J. 2012 Mar;33(3):315-20.
27. Castelo KMS, Bramante FS. Determination of the structural characteristics in youngsters from Ceará with Class II, division 1 malocclusion. Dental Press J Orthod. 2012 July-Aug;17(4):140-7
28. Uzuner F.D., Aslan B.I., Dinçer M. Dentoskeletal morphology in adults with Class I, Class II Division 1, or Class II Division 2 malocclusion with increased overbite. Am J Orthod Dentofacial Orthod. 2019 Aug;156(2):248-256.e2
29. Clark WJ. The twin block technique A functional orthopedic appliance system. Am J orthod Dentofacial Orthop. 1988;29(3):255-30.
30. DeVincenzo JP, Winn MW. Orthopedic and orthodontic effects resulting from the use of a functional appliance with different amounts of protrusive activation. Am J Orthod Dentofacial Orthop. 1989 Sep;96(3):181-90.
31. Lund DI. and Sandler PJ. The effects of Twin Blocks: A prospective controlled study. Am J.Orthod Dentofacial Orthop1998: 113(1), 104–110.
32. Illing HM, Morris DO, Lee RT. A prospective evaluation of Bass, Bionator and Twin Block appliances. Part I--The hard tissues. Eur J Orthod. 1998 Oct;20(5):501-16.
33. Tümer N and Gültan AS. Comparison of the effects of monoblock and twin-block appliances on the skeletal and dentoalveolar structures. Am J Orthod Dentofacial Orthop 1999;116:460-8.
34. Toth LR and McNamara JA Jr. Treatment effects produced by the twin-block appliance and the FR-2 appliance of Fränkel compared with an untreated Class II sample. Am J Orthod Dentofacial Orthop. 1999 Dec;116(6):597-609.
35. Trenouth MJ. Cephalometric evaluation of the Twin-block appliance in the treatment ofClass II Division 1 malocclusion with matched normative growth data. Am J Orthod Dentofacial Orthop. 2000 Jan;117(1):54-9.

36. Banks P., Wright J., O'Brien K. Incremental versus maximum bite advancement during twin-block therapy: a randomized controlled clinical trial. Am J Orthod Dentofacial Orthop.2004 Nov;126(5):583-8.
37. Gilla DS and Lee RT.Prospective clinical trial comparing the effects of conventional Twin- block and mini-block appliances: Part 1. Hard tissue changes Am J Orthod Dentofacial Orthop 2005; 127:465-72.
38. Sharmaa AA. And Lee RT. Prospective clinical trial comparing the effects of conventional Twin-block and mini-block appliances: Part 2. Soft tissue changes. Am J Orthod Dentofacial Orthop 2005; 127:473-82.
39. Jena Ak. , Duggal R., Parkashc H. Skeletal and dentoalveolar effects of Twinblock and bionator appliances in the treatment of Class II malocclusion: A comparative study. Am JOrthod Dentofacial Orthop 2006; 130:594-602.
40. Zupancic S., Pohar M., Farcnik F. and Ovsenik M. Overjet as a predictor of sagittal skeletalrelationships. Eur J. Orthod 30 (2008) 269–273.
41. Niu Y, Zhou H. Effect of functional appliances on mandibular growth on skeletal class II malocclusion: a systematic review. Hua Xi Kou Qiang Yi Xue Za Zhi. 2011 Aug;29(4):384-8.
42. Baysal A, Uysal T. soft tissue effects of twin block and herbest appliances in patients withclass II division 1 mandibular retrognathy. Eur J Orthod 2011; feb 28.
43. El kattan AE. Modified twin block appliance for class II division 1 treatment in mixeddentition. Msc department of orthodontics, Cairo university, 2012.
44. Ehsani S., Nebbe B., Normando D., Lagravere M.O. and Flores-Mir C. Short-term treatment effects produced by the Twin-block appliance: a systematic review and meta-analysis. Eur J Orthod,2008: 37(2), 170–176.
45. Giuntinia V., Vangelistia A., Masuccia C., Defraiab E., McNamara JA Jr, Franchi L. Treatment effects produced by the Twin-block appliance vs the Forsus Fatigue Resistant Device in growing Class II patients. Angle Orthod Sep 2015: 85(5);784-789.
46. Singh A., Chain S., Kulshrestha R., Gupta M., Passi D., Singh M. Comparison between conventional Twin block and a modified Essix twin block in adolescents with Class II malocclusion. Intl J Dent Research 2016; 1(1): 1-5
47. Patel P, Shanthraj R, Garg N, Vallakati A. Skeletal Class II division 1 malocclusion treated with twin-block appliance. Int J Orthod Rehabil 2017;8:31-7.
48. Van der Plas MC, Janssen KI, Pandis N, Livas C. Twin Block appliance with acrylic capping does not have a significant inhibitory effect on lower incisor proclination. Angle Orthod. 2017 Jul;87(4):513-518.
49. Elfeky HY., Fayed MS., Alhammadi MS., Soliman SAZ., El Boghdadi DM. Three- dimensional skeletal, dentoalveolar and temporomandibular joint changes produced by TwinBlock functional appliance. J Orofac Orthop. 2018 Jul;79(4):245-258.
50. Golfeshan F, Soltani MK, Zohrei A, Poorolajal J. Comparison between Classic Twin-block and a Modified Clear Twin-block in Class II, Division 1 Malocclusions: A Randomized Clinical Trial. J Contemp Dent Pract 2018;19(12):1456-1463.
51. Wooside DG, Metaxas A., altuna G. the influence of functional appliance

therapy on glenoid fossa remodeling. Am J Orthod Dentofacial Orthop. 1987 sep;92(3):181-98.
52. Baccetti T, Franchi L, Toth LR, Mcnamara JA Jr. Treatment timing for Twin-block therapy.Am J Orthod Dentofacial Orthop 2000;118:159-70.
53. Franchi L, Baccetti T, McNamara JA Jr: Mandibular growth as related to cervical vertebral maturation and body height. Am J Orthod Dentofacial Orthop 118:335-340, 2000.
54. Baccetti T, franchi L.The Fourth Dimension in Dentofacial Orthopedics: Treatment Timing for Class II and Class III Malocclusions. World J Orthod 2001;2:159-167.
55. Baccetti T, Franchi L, Mcnamara JA. An Improved Version of the Cervical Vertebral Maturation (CVM) Method for the Assessment of Mandibular Growth. Angle Orthod 2002;72:316–323.
56. O'brien K, Effectiveness of early orthodontic treatment with the Twin-block appliance: A multicenter, randomized, controlled trial. Part 2: Psychosocial effects. Am J Orthod Dentofacial Orthop 2003;124:488-95.
57. Faltin KJ., Faltin RM., Baccetti T., Franchi L., Ghlozzi B., Mcnamara JA Jr. long term effectiveness and treatment timing for bionator therapy. Angle Orthod. 2003 Jun;73(3):221- 30
58. Wong RW, Alkhal HA. and Rabie BA. Use of cervical vertebral maturation to determine skeletal age. Am J Orthod Dentofacial Orthop 2009;136:484.e1-484.e6.
59. Vijayalakshim P, Veershi A. management of severe class II malocclusion with fixed functional appliance: forsus. J Contemp Dent Pract 2011 May 1;12(3):216-20.
60. Ballrick J.W., Fields H.W., F. Beck F.M., Sun Z. Germak J. The cervical vertebrae staging method's reliability in detecting pre and post mandibular growth, Orthodontic Waves,(2013)72:3, 105-111.
61. Thiruvenkatachari B., Harrison J., Worthington H., O'Brien K. Early orthodontic treatment for Class II malocclusion reduces the chance of incisal trauma: Results of a Cochrane systematic review Am J Orthod Dentofacial Orthop 2015;148:47-59.
62. Montasser M., Viana G., Evans C. Secular trends in the timing of skeletal maturation as assessed by the cervical vertebrae maturation method. Eur J Orthod, Volume 39, Issue 2, 1 April 2017: 188–193.
63. Botkin, D. B. and Keller, E. A. Nuclear energy and the environment. In: Environmental Science. 3rd Ed. John Wiley and Sons, New York. 2000: 366-382.
64. MARION J.B. Physics in the Modern World (Second Edition), 1981.
65. Michael F. L'Annunziata. Radioactivity: introduction and history, 2007.

66. Haque, S.; Takinami, S.; Watari, F.; Khan, M. H. and Nakamura, M. Radiation effects of carbon ions and gamma ray on UDMA based dental resin. Dent mater J. 2001: 20(4): 325-338.
67. Oral, E.; Christensen, S. D.; Malhi, A. S.; Wannomae, K. K. and Muratoglu, O. K. (2006): Wear resistance and mechanical properties of highly crosslinked UHMWPE doped with Vitamin-E. J arthroplasty; 21(4): 580–591.
68. An Overview of Basic Radiation Effects on Polymers and Glasses. SAND2013-8003P.
69. Winkler S. Denture base resins. Dent Clin North Am 1984;. 28:287-97. 10

70. Alwan T.J. Effects of gamma radiation on the physical properties of PAni.MWCNT/PMMAfilms.
71. Murray, J. A.; Bruels, M. C. and Lindberg, R. D. Irradiation of Polymethylmethacrylate: In Vitro Gamma Radiation. J bone joint surg am; 1974; 56(2): 311-312.
72. Behr, M.; Rosentritt, M.; Faltermeier, A. and Handel, G. Electron beam irradiation of denture base materials. J mater sci mater med 2005; 16(2): 175-181.
73. Ferreira, F. G. D., Lima, M. A. G. de A., Almeida, Y. M. B. de, & Vinhas, G. M. Effect of the radiolitic sterilization in polyethylene/starch blends. Quím. Nova, 2008; 31(5), 1043– 1047.
74. Moorrees, Coenraad F. A.; Kean, Martin R. Natural head position, a basic consideration in the interpretation of cephalometric radiographs. Am J Physical Anthropology. 1958; 16(2):213-224.
75. Dahlberg G. Statistical methods for medical and biological students. New York: Interscience Publications; 1940. Br Med J. 1940 Sep 14; 2(4158): 358–359.