Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

ISSN NO. 2320-5407

Article DOI:10.21474/IJAR01/18560
DOI URL: http://dx.doi.org/10.21474/IJAR01/18560

RESEARCH ARTICLE

GEOMETRIC ANALYSIS OF THE MANDIBULAR FIRST PREMOLAR AND CORRELATION WITH ITS FUNCTIONS USING FINITE ELEMENT METHOD

Mostafa Aldesoki[1] and Khaled El-Sayed El-Haddad[2,3]

1. Dental School, Oral Technology, University Hospital Bonn, Germany.
2. Assistant Professor, Basic Oral Medical Sciences Department, College of Dentistry,Qassim University, Qassim, Saudi Arabia.
3. Assistant Professor, Department of Oral Biology, Faculty of Dentistry, Ain Shams University, Cairo, Egypt.

……………………………………………………………………………………………………....

Manuscript Info

……………………..

Manuscript History
Received: 20 February 2024
Final Accepted: 23 March 2024
Published: April 2024

Key words:-
Premolar, Finite Element Method, Occlusal Forces

Abstract

………………………………………………………………

Introduction: The geometric analysis is of important value for exploring the functional adaptation of the human teeth. The mandibular first premolar is one of the permanent teeth that has unique geometric features to properly perform its functions.

Purpose: To assess the geometric features of the mandibular first premolar functional and the stress analysis of the static occlusal forces using finite element method.

Materials & Methods: Ten human extracted mandibular first premolars were photographed from different aspects to analyze the geometric morphology of the premolars. Dimensional measurements were done by Image J software. Cone beam computerized tomographies were taken to the teeth to construct three-dimensional models for finite element analysis of 150 newtons axial load on buccal cusp tip and distal marginal ridge of each tooth.

Results: The descriptive and numerical geometric analysis of the images revealed increased lingual inclination and prominence of the buccal cusps in comparison to the lingual cuspsallowing the proper esthetic and masticatory functions. The finite element analysis revealed that there is harmonious stress distribution with relatively high stress concentration in the dentin of the cervical regions of the crowns and roots. The tooth morphology affects the stress distribution.

Conclusion: The mandibular first premolar geometric characteristics are critical toits functional performance. The lingual inclination and the cuspal interrelations are of great importance in the geometric pattern of the mandibular first premolars. The stress distribution is homogeneous in the tooth and supporting tissues with a relative increase in the cervical region.

……………………………………………………………………………………………………....

Introduction:-

One of the main functions of teeth is mastication. The normal tooth form and alignment are essential to perform this function efficiently [1]. The mandibular first premolar is formed of four lobes, it has a well-developed, only functioning, buccal cusp and a smaller non-functioning lingual cusp. The mandibular first premolar resembles

Corresponding Author:- Khaled El-Haddad
Address:- Faculty of Dentistry, Ain Shams University, Cairo, Egypt.

mandibular canine in the sharp buccal cusp, the faciolingual dimension and the diamond shaped occlusal outline. While it resembles second mandibular premolar except the sharp buccal cusp and the size and number of the lingual cusps [2]. The increased lingual inclination of the first mandibular premolar has a prominent role in the stress distribution of the occlusal loads [3].

The proper occlusion of the posterior teeth is a primary requirement for performing the masticatory function. There is no fixed scheme of the occlusal contact in all individuals in the literature, as these contacts vary according to many factors including the discrepancies in the teeth and jaws sizes and morphologiesand also, the jaw relations. Hence, there are several occlusal schemes in healthy people, all attempted to represent the ideal occlusion, however, these occlusal patterns could be found only in few individuals [4]. One of the suggested patterns stated that the centric stop contacts in the mandibular first premolar are buccal cusp and distal marginal ridge [2].

Human teeth are subjected to occlusal forces, or loads, which are commonly defined by the expression of their axial components. Comprehensive and accurate knowledge about these loads are crucial for the optimum management in different fields of dentistry such as implant dentistry, restorative dentistry and orthodontics [5]. Moreover, the occlusal forces are correlated to the teeth stability within the supporting tissues. This correlation should be considered during the restoration of the occlusal surfaces to avoid the possible deteriorating effects on the periodontium [6].

One of the important aspects of the masticatory forces is the occlusal load distribution. This distribution is affected by many factors. **Kumagai et al.** concluded that the occlusal loads on the premolars are inversely proportional to the degree of clenching. The authors reported the importance of the occlusal forces'control in the analysis of the occlusal contacts [7]. The measurement of the biting forces revealed their wide range, depending on the anatomical and physiologic variation between the individuals. Also, the biting forces measurement tool accuracy is a significant factor in this regard [8]. Several tools and techniques are used to assess the occlusal forces. The use of the three-dimensional models has been employed in the recent years and was found to be efficient in the evaluation of both the normal masticatory system and the prosthodontic appliances quality [9].

Finite Element Method (FEM) or Finite Element Analysis (FEA) is a digital technique used to analyze the stresses and the deformations occurring in a pre-designed three dimensional geometric model of the tested structure. This three dimensional model is segmented into extremely fine elements (called finite elements). These elements are interconnected via nodes. The constructed FE model could be formed of more than one material (such as models of combined dental tissues). In this case, each material is designated in the software by specific properties. Then thespecified applied load is determined and the boundary conditions (The fixed base against which the load would be applied) is allocated. Various software packages are used in the FEM to construct the models, simulate the applied loads and to analyze the stresses and deformations occurred in the tested materials [10].

In recent years, FEM had numerous applications in dentistry to investigate the mechanical properties of dental tissues and restorative materials. FEM has many advantages, it is inexpensive, doesn't cause tissue damage, reproducible and provides relatively accurate results [11]. Moreover, FEM has no ethical considerations and allows modifications in the study designs [12]. However, FEM limitations are reported, including the inability to perfectly simulate the clinical conditions. Also, the stress analysis is usually performed using static loads which do not reflect the real loads in the oral cavity. Thus, FEM studies should be complemented by clinical trials [10].

To our knowledge, there are few studies conducted to geometrically analyze the mandibular first premolars in correlation to their functions. The aim of the current work was to analyze the main geometric features and dimensions of a sample of human mandibular first premolars and to assess the primary axial occlusal load via the FEM.

Materials and Methods:-

The photographic imaging and analysis

Tenextracted human mandibular first premolars were used in this study. The teeth were photographed by a digital camera from five directions (buccal, lingual, mesial, distal and occlusal) with a scale in the image to be used in the software of image analysis. The general descriptive geometric data (e.g. the geometric outlines) were analyzed. Furthermore, the images with clear measurable details were analyzed by Image J software (version 1.53e) to measure different dimensions (Crown height, root length, mesiodistal and buccolingual dimensions at the cervix and crown). The numerical data were tabulated and represented by mean values and standard deviation.

Finite element method procedures

The teeth underwent scanning using a PlanmecaProMax 3D Mid cone-beam computed tomography (CBCT) machine (PlanmecaInc, Helsinki, Finland). The machine settings were configured to 90 kV and an X-ray beam current of 12.5 mA, with a voxel size of 75 µm. The scanning process lasted for 15 seconds, generating a total of 668 slices for subsequent modeling.

The scanned data were then imported into a 3D segmentation and editing software package (Mimics Innovation Suite, Mimics 14.0 / 3-matic 7.01; Materialise, Leuven, Belgium) to generate the surface model. Within the Mimics software, masks for enamel and dentin were created using thresholding and region growing tools. These masks were then utilized to produce 3D models of enamel and dentin, which were later imported into 3-Matic software in Standard Tessellation Language (STL) format.In 3-Matic software, the enamel and dentin geometries underwent thorough error checking. Furthermore, the bone geometry was modelled to comprise an inner block representing trabecular bone, with dimensions of 11.5 mm buccolingual, 10.5 mm mesiodistal, and 21.5 mm in height, accompanied by an outer shell measuring 1 mm in thickness to simulate cortical bone. Lastly, a periodontal ligament (PDL) with a thickness of 0.3 mm was meticulously modeled**(Fig. 1).**

Subsequently, all geometries were imported into ANSYS Workbench software (version 14.0, ANSYS Inc., Houston, USA) in the CDB file format for FEA. Within ANSYS Workbench, the volume mesh was created utilizing 'Solid187' 10-node linear tetrahedral elements, with a maximum element size set to 0.5 mm **(Fig. 2)**. The total count of nodes and elements is detailed in **table (1).** Material properties were subsequently assigned according to their elastic modulus and Poisson's ratio. Enamel, dentin, bone, and the PDL were all assumed to possess linear, elastic, homogeneous, and isotropic properties. The specific material properties, including the modulus of elasticity and Poisson's ratio, for each material are listed in **table (2).** Furthermore, bonded contact interactions were assumed among all contact bodies.

Concerning the boundary conditions, the base of the bone block was established as a fixed support in all directions. A nodal force of 150 N, aligned parallel to the long axis of the tooth, was applied and evenly distributed across two contact points: the distal marginal ridge and the tip of the buccal cusp**(Fig. 2).** Each of these points encompassed 10 selected nodes, ensuring uniformity in node selection and distribution across all models for standardization purposes. Subsequently, linear static analysis was conducted to calculate the total von Mises stress values for all models.

Table (1):- The number of nodes and elements of all objects of the finite element model.

Tooth serial number	Nodes	Elements
1	28,620	15,618
2	38,789	21,323
3	45,416	25,048
4	39,898	21,889
5	54,777	31,066
6	76,431	45,117

Table (2):- Material properties assigned to different objects in the finite element model.

Material	Elastic modulus (MPa)	Poisson’s ratio
Enamel	84100	0.33
Dentin	18600	0.32
Cortical bone	13700	0.30
Trabecularbone	1370	0.30
PDL	70	0.45

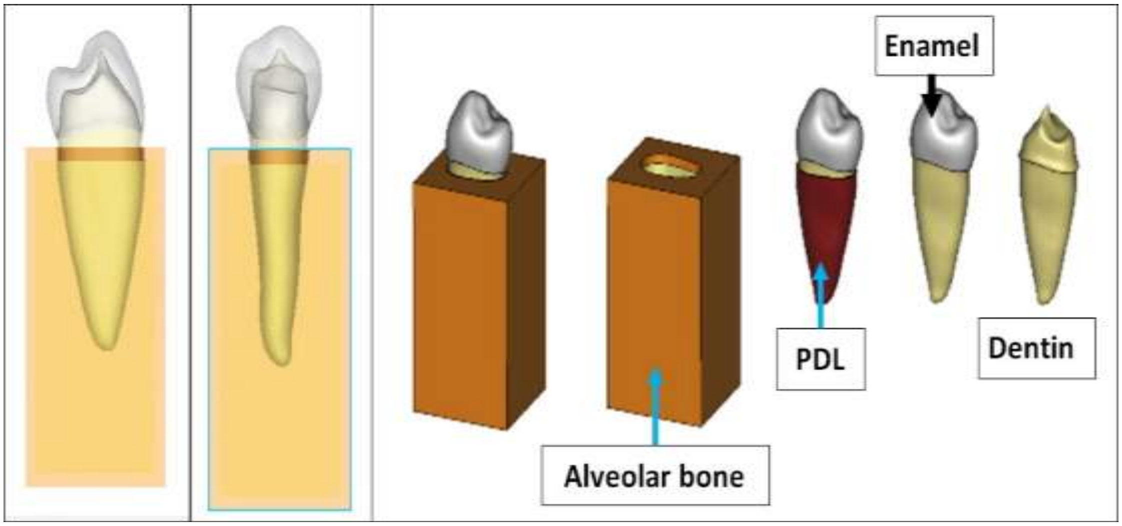

Fig. (1):-Three dimensional models generation with distinct enamel and dentin layers. The alveolar bone and periodontal ligament (PDL) are added to the model.

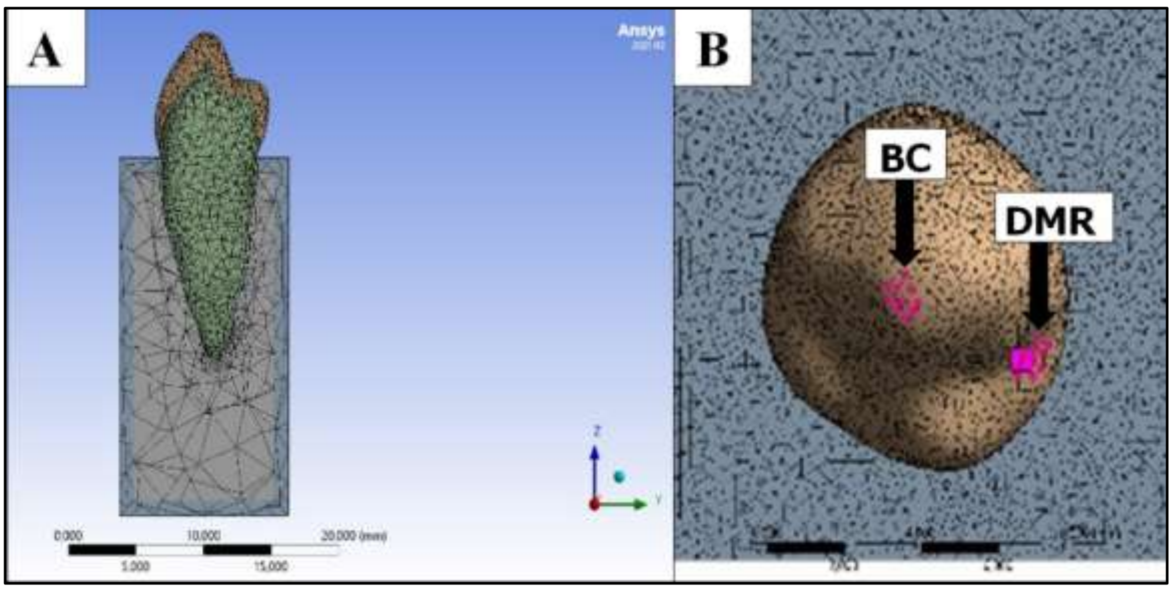

Fig. (2):-(A)Three-dimensional finite element volume mesh of the model. (B) The nodes that were subjected to the occlusal loads (BC= buccal cusp. DMR= Distal marginal ridge).

Results:-

General geometric criteria of the mandibular first premolar

The descriptive analysis of the photographic images revealed common geometric features in the tested samples including the crown geometric outlines and the relative positions of the cusps. The following criteria are the main geometric features that could be correlated with the main functions of the mandibular first premolars:

A- The buccal aspect showed roughly trapezoid geometric outline of the crown with the shortest side cervically and the contact areas were almost in the same level in most samples. The buccal cusp was well-developed resembling the canine cusp which allows for the esthetic role of mandibular first premolar in combination with the canine. The apical third of the root was curved in most of the samples, predominantly to the distal side **(Fig. 3a).**

B- The proximal aspect showed roughly rhomboid geometric outline due to the lingual inclination which was accentuated, this leads to the shifting of the buccal cusp towards the midline and aligned almost with the midline of the crown in all samples. The lingual cusp was less developed than buccal cusp and its tip was aligned with the lingual border of the root**(Fig. 3b).**The geometric significance of this finding is that the buccal cusp is the only occluding cusp which necessitated its positioning at the midline to receive the occlusal load and transfer it to the

center of the long axis for better stress distribution. Moreover, the shortening of the lingual cusp prevents its protrusion lingually that would occur as a result of the increased lingual inclination. This protrusion could interfere with the tongue in addition to that the cusp tip would be out of the root confines, which increases the deteriorating forces on the unsupported cusp.
C- The occlusal aspect revealed rounded or diamond geometric outlines with clearly observed transverse ridge in many samples. The buccolingual and mesiodistal dimensions were almost equal **(Fig. 3c).**

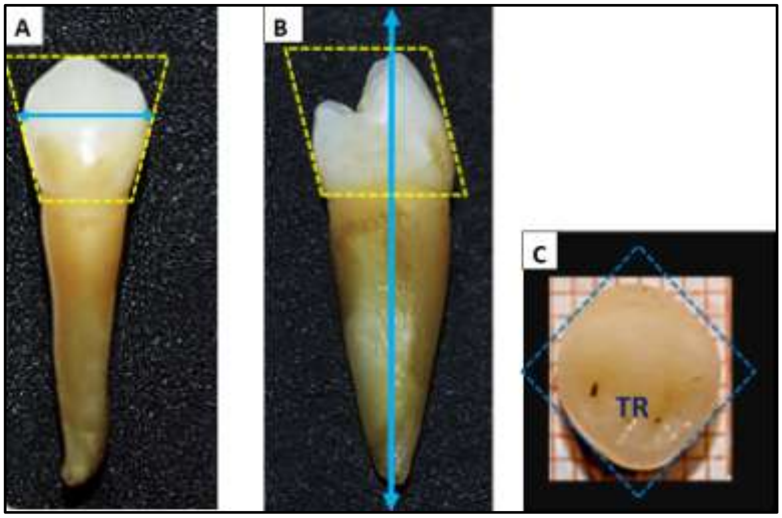

Fig. (3):-(A)Buccal aspect on one sample with trapezoid outline and nearly parallel contact areas (arrow). (B) Mesial aspect with rhomboid crown outline and the buccal cusp aligned with the midline (arrow). (C) Occlusal aspect of one sample with symmetric diamond symmetric outline and the observed transverse ridge (TR).

Dimensional details of the mandibular first premolar
The dimensions of the measured samples were consistent in the tested parameters (low standard deviations) except for the root length which showed apparent variations between the samples reflected by a relatively high standard deviation **(Table 3).**
Table (3):- The mean and standard deviation of the measured parameters.

The measured dimension	Mean	Standard deviation
Mesiodistal dimension at the cervix.	5.44	0.30
Mesiodistal dimension at the crown.	7.81	0.49
Crown height.	8.69	0.91
Root length.	15.24	2.15
Buccolingual dimension at the cervix.	7.46	0.60
Buccolingual dimension at the crown.	8.85	0.72

Finite element analysisresults
The tested samples were subjected to an axial load (150 N) on the buccal cusp tip and distal marginal ridge of each premolar. The descriptive analysis of the representative color-coded images of the FEA revealed that the stresses were homogeneously distributed all over the tooth structure and the supporting tissue. The stress concentration was observed mainly in three regions, the two sites of load application and the cervical regions of crown and root at the distal surface**(Fig. 4a).**

The highstressvalues in the regions of load application (buccal cusp tip and distal marginal ridges) was restricted toenamel **(Fig. 4a, b).**The cervical parts of the crowns and roots revealed the maximum stress values in most of samples particularly in dentin and PDL. It was noticed that these increased stresses occupied wider areas in the cervical root dentin in the teeth with apparently more root curvatures in the apical third**(Fig. 4c, d).**

The alveolar process received almost medium level of stresses with no marked increase in stress valueswith occasionally detected increased stresses in some regions such as those adjacent to the cervical part of the tooth**(Fig. 4e).**In many samples, the enamel of the mesio-occluso-buccal angles showed minimal stress values **(Fig. 4f).**

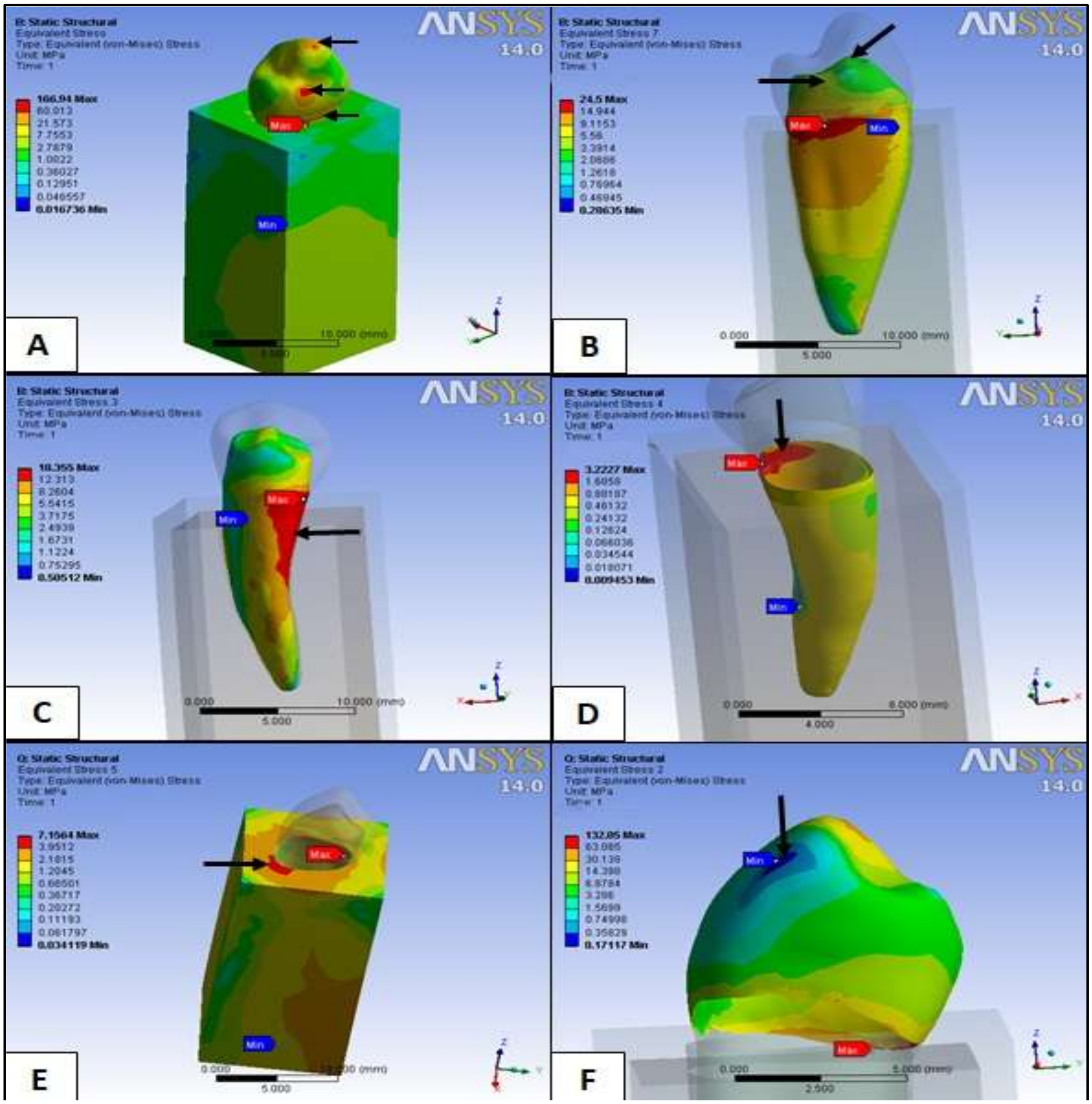

Fig. (4):-FEA imagesshowing (A): Homogeneously distributed stresses with concentration in the enamel of buccal cusp, distal marginal ridge and the cervical portion of crown and root at the distal surface. (B): No detected high stress values in the dentin of buccal cusp tip and distal marginal ridges (arrows). The dentin (C) and the PDL (D) of the cervical region had maximum stresses (arrows). (E): The alveolar process showed high stress in the cervical region (arrow). (F): Enamel of the mesio-occluso-buccal angle had minimal stresses (arrow).

The quantitative analysis of the stress distribution was performed via the recording of von Mises stress values in specific regions of six selected representative samples. The detailed numerical recordings are listed in **table (4)**. The buccal cusp tip and distal marginal ridges showed the highest stress values. While the least values were recorded in the lingual cusp tip and the root apex. The transverse ridge and the mesial marginal ridge revealed intermediate stress values. Two samples revealed marked increase in the stress values at the buccal cusp tip in comparison to the other samples. One of these two samples showed high stress on the distal marginal ridge also. By examining the images of these two samples, it was found that one of them had a slightly deviated transverse ridge**(Fig. 5a).**The other showed relatively increased discrepancy between the length of the buccal cusp slopes compared with the other samples**(Fig. 5b)** and also had slight deformity in the geometric outline of the occlusal aspect in the mesiolingual region **(Fig. 5c).**

Table (4):- Detailed numerical recordings of maximum von Mises stress (MPa) in six regions in the selected representative samples.

Tooth number	Buccal cusp tip	Lingual cusp tip	Mesial marginal ridge	Distal marginal ridge	Transverse ridge	Root apex
1	50.36	4.12	5.42	83.86	18.85	2.1
2	54.1	2.03	3.33	58.82	13.63	2.12
3	102.81	3.3	2.53	62.73	7.32	2.57
4	37.47	2.5	4.22	39.67	13.17	1.4
5	62.93	2.09	2.62	74.5	10.12	0.362
6	314.46	1.27	4.43	279.15	18.33	1.33
Mean	103.69	2.55	3.76	99.79	13.57	1.65
Standard Deviation	105.62	1.01	1.13	89.14	4.51	0.79

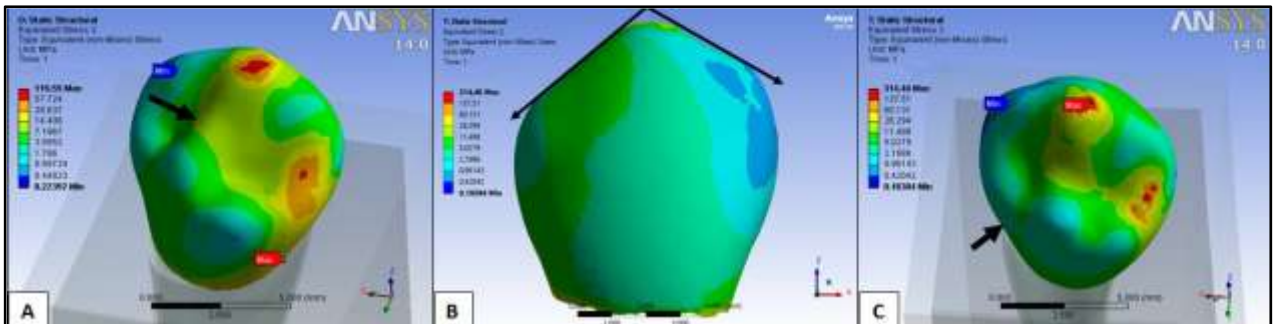

Fig. (5):-FEA images of the two samples with eccentric values. (A) One sample showed a slightly deviated transverse ridge (arrow). The other showed (B) discrepancy between the length of the buccal cusp slopes (arrows) and (C) slight deformity in the mesiolingual region.

Discussion:-

The current study aimed to analyze the main geometrical criteria of the mandibular first premolar and to correlate between these features and the static axial load distribution using the finite element analysis (FEA). The mandibular first premolar has specific function as a transition between the canine and the second premolar [13]. Consequently, its morphology is adapted for this transition and requires the analysis to explore the correlation between its geometric features and its functional performance.

In the present study, two techniques were used for the analysis. The first was the dimensional measurement on photographic images, using image J software, to investigate the dimensions of the samples and demonstrate the basic geometric concepts. The second method was the use of three-dimensional models performed via cone beam CT images to assess the occlusal loads. The use of computational models for the three-dimensional load analysis enhances the masticatory performance assessment [9]. FEA is considered an efficient tool to explore the biomechanics of various tooth structures, thus, it is recently used in dentistry mechanical researches [11,14] due to its several advantages including the repeatability and the absence of ethical considerations in its procedure [12].

Although one of the limitations of our work is the restriction to axial load application, however, this selection of axial forces agreed with **DeLas Casas et al.** [5] who stated that the dental masticatory forces are commonly represented in research using the axial compartment of the load only. In the current study, 150 Newton (N) was selected to be applied. This was in harmony with **Maravić et al.** [15] who reported that 150 N on the occlusal surface mimics the ordinary biting force. In the present work, the occlusal load was applied on two occlusal contacts which are the buccal cusp tip and the distal marginal ridge. These points were selected in accordance to the centric stops of the supporting cusps and marginal ridgespreviously reported in 1993 by **Ash** [2].

Our results revealed the common geometric outlines of the buccal, proximal and occlusal aspects. The trapezoid geometric outline of the buccal aspect and the sharp buccal cusp, resembling the mandibular canine might be important to the first premolar to assist the mandibular canine in the esthetic function of teeth. Additionally, **Vuković et al.** [13] have reported that the mandibular first premolar performs a similar role asthe canine in mastication. Regarding our numerical results of the premolar dimensions, the measurements were comparable to those reported by **Ash** in 1993 [2] in terms of the crown height, root length, mesiodistal dimensions. However, the buccolingual dimensions were slightly of larger values.

The geometric analysis of the unique accentuated rhomboid outline of the proximal aspect could be explained as follows: The rhomboid outline is accentuated due to the increased lingual inclination of the crown over the root to obtain the proper intercuspation with the opposing teeth in addition to bringing the long axes of the opposing teeth parallel [2]. This increase in the inclination would lead to relative lingual protrusion of the lingual cusp, which necessitated the shortening of the lingual cusp to avoid undesirable interference with the tongue and to ensure the alignment of the cusp within the confines of the root. Hence, this shortened lingual cusp is out of occlusion leading to that the buccal cusp is the only occluding cusp. This is compensated by the well-developed buccal cusp which is aligned almost at the midline buccolingually. This size and position of the buccal cusp provided an appropriate load direction along the long axis of the tooth. This explanation is in harmony with **Ahmić et al.** [3] who correlated between the lingual inclination and the proper stress distribution in the mandibular first premolar.

The FEA in the present study revealed the proper von Mises stress distribution in the premolar under the axial load applied. This agreed with **Yang & Chung** [16] who conducted three dimensional FEA of the stresses over the premolars. The authors reported that the axial occlusal loads resulted in a relatively low von Mises stress values and resulted in decreased stresses on the tooth and PDL. Moreover, our results might be explained by the nature of mandibular bone which tends to absorb the occlusal forces more than maxilla [17].

One of the prominent observations in the current study was the stress concentration on the cervical region particularly in dentin and PDL. This finding coincides with several previous studies reported that the lower first premolar is the most common tooth to be affected by a lesion called (abfraction), a non-carious lesion in the form of microstructural loss of the hard tooth structures as a result of the occlusal load concentration in this region [3, 18-21].

Our results revealed high stresses in the buccal cusp which decrease towards the lingual cusp. This was in accordance with**Ahmić et al.** [3] who stated recorded maximum stress on the occlusal contacts particularly the buccal cusp tip and reported decrease in the tissue deformation in the lingual portion. Moreover, the affection of dentin more than enamel in our results coincides with **Yang & Chung** [16]who stated that the dentin lesions are exaggerated with the occlusal stresses.

In our results, there was a correlation between the size of the root dentin area subjected to high stresses and the degree of the root curvature. This might be explained by the possible eccentric forces generated by the increased root curvature. These eccentric forces might aggressively affect the supporting tissue and cause PDL trauma [16].

Interestingly, in our study, there were occasional variations in a few samples in the stress distribution. These samples were characterized by some anatomical deviation from the regular morphology which might affect the FEA results [3]. Although our results presented a correlation between the fundamental geometric features of the mandibular first premolar. However, the results obtained from FEA need to be augmented by complementary in vivo models for obtaining valid and relevant conclusions [22].

Conclusion:-

The mandibular first premolar is a uniquely designed human tooth with geometric features that arecorrelated to its functions. The FEA revealed harmonious stress distribution with relative stress concentration in the cervical region particularly in dentin. The lingual inclination and the cuspsize and position are important in the functional performance and stress distribution. Further studies are needed that applying different forces' directions and assuming possible abnormal anatomical features to evaluate the impact of these abnormalities on the stress distribution within the human dental tissues.

Ethical considerations:

The research had an ethical approval from the ethical research Committee, Faculty of Dentistry, Ain Shams University (Code: FDASU-Rec PC 072326)

Conflict of interest:
The authors declare that there is no conflict of interest.

Funding:
No funding received.

References:-

1- Boushell, L.W., &Sturdevant, J.R. (2019). Clinical Significance of Dental Anatomy, Histology, Physiology, and Occlusion. In: Ritter, A.V., Boushell, L.W., & Walter, R., Editors., Sturdevant's Art and Science of Operative Dentistry, pp. 1-39, Elsevier. https://doi.org/10.1016/B978-0-323-47833-5.00001-0.
2- Ash, M.M. (1993). Wheeler's dental anatomy, physiology, and occlusion., 7th edition W.B. Saunders, Philadelphia.
3- AhmićVuković, A., Jakupović, S., Zukić, S., Bajsman, A., GavranovićGlamoč, A., &Šečić, S. (2019). Occlusal Stress Distribution on the Mandibular First Premolar - FEM Analysis. Actamedicaacademica, 48(3), 255–261. https://doi.org/10.5644/ama2006-124.265
4-Carlsson, G.E., Haraldson, T., &Mohl, N.D. (1988). The dentition. In: Mohl, N.D., Zarb, G.A., Carlsson, G.E., &Rugh, J.D., Editors. A textbook of occlusion, p. 57-69. Chicago: Quintessence.
5- de Las Casas, E. B., de Almeida, A. F., Cimini Junior, C. A., Gomes, P.deT., Cornacchia, T. P., &Saffar, J. M. (2007). Determination of tangential and normal components of oral forces. Journal of applied oral science :revista FOB, 15(1), 70–76. https://doi.org/10.1590/s1678-77572007000100015
6- Ishihara, H. (2000). Kokubyo Gakkai zasshi. The Journal of the Stomatological Society, Japan, 67(4), 310–321. https://doi.org/10.5357/koubyou.67.310
7- Kumagai, H., Suzuki, T., Hamada, T., Sondang, P., Fujitani, M., &Nikawa, H. (1999). Occlusal force distribution on the dental arch during various levels of clenching. Journal of oral rehabilitation, 26(12), 932–935. https://doi.org/10.1046/j.1365-2842.1999.00473.x
8- van der Bilt, A., Tekamp, A., van der Glas, H., &Abbink, J. (2008). Bite force and electromyograpy during maximum unilateral and bilateral clenching. European journal of oral sciences, 116(3), 217–222. https://doi.org/10.1111/j.1600-0722.2008.00531.x
9- Röhrle, O., Saini, H., &Ackland, D. C. (2018). Occlusal loading during biting from an experimental and simulation point of view. Dental materials : official publication of the Academy of Dental Materials, 34(1), 58–68. https://doi.org/10.1016/j.dental.2017.09.005
10- Trivedi S. (2014). Finite element analysis: A boon to dentistry. Journal of oral biology and craniofacial research, 4(3), 200–203. https://doi.org/10.1016/j.jobcr.2014.11.008
11- Mohan, M., Mohammad, L., Cholayil, N., Vats, S., Salman Kuttikkodan, M., &KodumbilayiparambilAnto, J. (2024). Stress Distribution on Maxillary Canines Following Restoration With Different Dimensions of Metal and Fiber Posts: A Finite Element Study. Cureus, 16(1), e53266. https://doi.org/10.7759/cureus.53266
12- Huempfner-Hierl, H., Schaller, A., Hemprich, A., &Hierl, T. (2014). Biomechanical investigation of naso-orbitoethmoid trauma by finite element analysis. The British journal of oral & maxillofacial surgery, 52(9), 850–853. https://doi.org/10.1016/j.bjoms.2014.07.255
13- Vuković, A., Zukić, S., Bajsman, A., &Selmanagić A. (2013). Basics of teeth morphology and dental anthropology [in Bosnian]. 1st ed. Sarajevo: Faculty of Dentistry University of Sarajevo.
14- Jakupović, S., Anić, I., Ajanović, M., Korać, S., Konjhodžić, A., Džanković, A., &Vuković, A. (2016). Biomechanics of cervical tooth region and noncarious cervical lesions of different morphology; three-dimensional finite element analysis. European journal of dentistry, 10(3), 413–418. https://doi.org/10.4103/1305-7456.184166
15- Maravić, T., Vasiljević, D., Kantardžić, I., Lainović, T., Lužanin, O., &Blažić, L. (2018). Influence of restorative procedures on endodontically treated premolars: Finite element analysis of a CT-scan based three-dimensional model. Dental materials journal, 37(3), 493–500. https://doi.org/10.4012/dmj.2017-064.
16- Yang, S.M., Chung, H.J. (2019). Three-dimentional finite element analysis of a mandibular premolar with reduced periodontal support under a non-axial load. Oral Biol Res, 43, 313-326. https://doi.org/10.21851/obr.43.04.201912.313
17- Suzuki M. (2006). Kokubyo Gakkai zasshi. The Journal of the Stomatological Society, Japan, 73(1), 79–89. https://doi.org/10.5357/koubyou.73.79
18- Jakupovic, S., Vukovic, A., Korac, S., Tahmiscija, I., &Bajsman, A. (2010). The prevalence, distribution and expression of noncarious cervical lesions (NCCL) in permanent dentition. Materia Socio-Medica, 22(4), 200-204.

19. Aw, T. C., Lepe, X., Johnson, G. H., &Mancl, L. (2002). Characteristics of noncarious cervical lesions: a clinical investigation. Journal of the American Dental Association (1939), 133(6), 725–733. https://doi.org/10.14219/jada.archive.2002.0268.
20. Khan, F., Young, W. G., Shahabi, S., & Daley, T. J. (1999). Dental cervical lesions associated with occlusal erosion and attrition. Australian dental journal, 44(3), 176–186. https://doi.org/10.1111/j.1834-7819.1999.tb00219.x
21- Borcic, J., Anic, I., Urek, M. M., &Ferreri, S. (2004). The prevalence of non-carious cervical lesions in permanent dentition. Journal of oral rehabilitation, 31(2), 117–123. https://doi.org/10.1046/j.0305-182x.2003.01223.x
22- Vaidyanathan, A. K., &Banu, R. F. (2022). Finite element analysis - Concepts for knowledge and implementation in dental research. Journal of Indian Prosthodontic Society, 22(3), 211–214. https://doi.org/10.4103/jips.jips_299_22.