BONE DENSITY ASSESSMENT OF MIDPALATAL SUTURE USING GRAYSCALE VALUES-A CBCT STUDY

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ABSTRACT

Objective

To assess the predictability of grayscale values in a CBCT scan to assess the level of maturation of midpalatal suture density using CBCT modality

Materials and Methods:

The 58 CBCT images of maxillary arch of subjects belonging to the age group 5-32 years were evaluated to assess morphologic stages of the midpalatal suture maturation stages A to E based on the Angeliere classification using the grayscale values. One-way ANOVA test was used to check the variation of grayscale in different groups of mid palatal suture classification. Pearson's correlation test was used to determine the correlation between the age of the subjects and grayscale values. An arithmetic calculation was done to convert the grayscale values into Hounsfield units to assess bone density according to the Misch's Classification.

Results- Mean and standard deviation of the grayscale value corresponding to the palatal maturation stage were assessed and its Hounsfield units (HU) were obtained by using the mathematicalformula. There was a statistically significant difference among the stages. No significant difference was observed between stage D and E (p-value >0.05). There was a significant correlation between the age of the patient and the corresponding grayscale value (r =0.599, p=0.00).

Conclusion- A statistically significant difference between the ossification stages of the mid palatine suture and grayscale values was obtained from CBCT and can be hence used as an alternate method for checking bone density. There is an increase in grayscale value observed as the age of the subjects increases.

Keywords: Cranial Sutures, Maxillary Expansion, Cone-Beam Computed Tomography, Bone Densities

1. INTRODUCTION.

Management of maxillary arch constriction in adult patients poses various arch challenges especially concerning the density assessment of the bone in the mid palatal suture. The density of bone-related to various stages of ossification based on the age of the patient plays an important role in selecting the correct choice of the arch expander. Rapid maxillary expansion (RME) is a procedure in orthodontic treatment for the correction of constricted maxillary arch in young patients(1). However, expansion in adolescent patients where the mid-palate sutures would have attained significant sutural interdigitation requires the use of more invasive methods. The two methods commonly advocated in adolescent and young adults are a non-surgical modality of expansion like miniscrew assisted rapid palatal expansion (MARPE) or surgically by using surgical assisted rapid palatal expansion (SARPE).

The difficulty which many orthodontists face is the time point to decide which arch expansion modality is best suitable(2,3)(4). Many studies suggest rapid maxillary expansion should be used before puberty and mini screw assisted rapid palatal expansion (MARPE) (5,6) can be used post-puberty. The mid palatal suture is one of the most important regions of resistance to the expansion of the maxilla and as age progresses the interdigitation of suture begins, offering resistance to expansion(7). The type of appliance used and the anchorage to be employed should be planned based on the maturational stages of the maxillary suture(8). Slow maxillary expanders can be used effectively in young patients whereas rapid palatal expanders can produce skeletal expansion at later ages. Surgical assisted rapid palatal expansion (SARPE) and miniscrew assisted rapid palatal expansion (MARPE) are the choice of treatment in cases where ossification of the suture is complete. It is understood from several studies that chronological age is unreliable for determining the developmental status of the suture during growth. Understanding the individual variability in the developmental status of the mid palatal suture is necessary for the choice of treatment, whether RME or MARPE as a less invasive alternative to SARPE (2)(9)(8).

CBCT can be used as a reliable diagnostic tool in cases where 3D assessment is essential for making the most pertinent treatment decision(10). The visualization of mid palatal suture density through the lesser invasive CBCT will be superior to CT due to its small FOV which is focused on the midface and hence the resolution is much better than the CT. However, unlike a CT scan, the CBCT scans do not have the capabilities of determining the Hounsfield units to accurately check bone density. An alternate method would be to check the grayscale units in a CBCT and check its predictability as most orthodontic patients are subject to mainly a CBCT scan as a part of diagnosis and treatment planning and assessment of airway(11). Therefore, this study was to assess the level of maturation of midpalatal suture in terms of density by evaluating the changes in the grayscale value from a CBCT.

2. METHODS AND METHODOLOGY

This was a retrospective study that was done on pre-treatment CBCT scans of subjects who reported to the dental hospital for various treatments over a period of ten months (June 2019 to March 2020). The sample size for the present study was determined as 58 with a power of 95% and an alpha error of 0.05 using T-testusing G*Power 3.0.10 software. This study design was approved by the institutional ethical committee (SDC/SIHEC/2020/DIASDATA/0619-0320). Among subjects who reported to the hospital for dental treatment of impacted teeth, mandibular trauma, orthognathic surgery, temporomandibular joint abnormalities, external and internal tooth resorption etc., good quality CBCT scans belonging to the age group 5-32 years, with correct head positions were chosen(10). CBCT scans with poor quality, patients with a history of cleft palate, maxillary palatal trauma or palatal bone disorders, CBCT scans which were not sharp due to patient movements or any other conditions which made it difficult to identify the landmarks were excluded from the study. A total of 100 consecutive CBCT records were collected and 58 CBCT scans were selected based on inclusion and exclusion criteria.

The CBCT scans included in the study were taken using Orthophos XG 3D (Dentsply Sirona, UK) machine with the settings: 85KV, 10 mA, exposure time 15 seconds, voxel 0.4mm and FOV 15x12cm; with the patient in the natural head position and the lower borders of the orbit were aligned with the Frankfort Horizontal plane. The CBCT images were converted to digital imaging and communication in medicine (DICOM) format. The analysis of the computed images was performed using Galileo's Sidexis Viewer 1.9, Dentsply Sirona imaging software. Standardization of the axial, coronal, and sagittal slice for suture analysis was done. The most appropriate axial slice for assessing the mid palatal suture was used by taking the central cross-sectional slices through the mid-portion of the trabecular bone of the palate, outlined by the oral cavity and the floor of the nasal cavity in the mid-sagittal section. The two examiners (A.M) and (S.K) analyzed the CBCT scans and categorized them according to the five different palatal sutural maturation stages i.e. A, B, C, D, E. Following the identification of suture, bone density was evaluated using the grayscale value of the suture using the tool available in the software. On the axial slice of the maxilla, the mid palatal suture was divided into three equal sections (M1, M2, M3). The grayscale value of the mid palatal suture in the maxillary region was the average of the gray values of its three sections. The grayscale value of the mid palatal suture was recorded and the highest recurring grayscale value at the region of interest was noted (Figure 1-4). Re-evaluation was done in case of disparity among the observations of two examiners and the observations were reconfirmed. All measurements were entered into the Excel spreadsheet.

Statistical Analysis

The data obtained were subjected to statistical analysis using Statistical Package for Social Sciences version 20.0 (SPSS Inc., Chicago, IL, USA). Mean, standard deviation, and standard error of grayscale values in different groups were determined and tabulated. One-way ANOVA test was used to check the variation of grayscale in different groups of mid palatal suture classification. Pearson's correlation test was used to determine the correlation between the age of the subjects and grayscale values.Intra operator reliability was checked by Cronbach's Alpha test after two weeks. Kappa statistics were used to evaluate inter-operator reliability between the observations by two observers (A.M, S.K). The mathematicalformula (HU = −61.098 + 1.178 × grayscale)(12) was used to determine the Hounsfield units (HU) obtained from the corresponding mean and standard deviation of grayscale values.

3. RESULTS

The mean, standard deviation, standard error, and significance of grayscale values of the CBCT of subjects included in the study was calculated and tabulated in the table (1). The mean and standard deviation of the age of the subjects included in the study was tabulated in the table (2). Sample size distribution of morphological maturation stage among males and females was tabulated in the table (3). The sample One-way ANOVA test reported a p-value of 0.00 indicating that there was a statistically significant difference among the stages. No significant difference was observed between stage D and E (p-value >0.05). The mean, standard deviation of grayscale values, and its corresponding converted Hounsfield units (HU) obtained by using the mathematicalformula (HU = −61.098 + 1.178 × grayscales)(12) is tabulated in the table (4). A mean grayscale value of 494.50+/-37.47, 870+/-42.32, 1199.07+/-97.52, 1388.92 +/-167.24 and 1493.71 +/- 111.31 was obtained for stages A, B, C, D, E respectively. Pearson correlation test was done to assess the correlation between age and grayscale value (r =0.599, p-value=0.00).Intra-operator reliability by Cronbach's Alpha test was 0.980 and the inter-operator reliability by Kappa statistics was 0.321.

4. DISCUSSION

There was an increase in grayscale values observed as age increases and a statistically significant difference was observed between the groups (ANOVA test; p-value- 0.00) (Figure 5, 6). No significant difference was observed between groups D and E (p-value >0.05). There is no difference in the higher limits of standard deviation for stages D and E. There was a significant correlation between the age of the patient and the corresponding grayscale value (Figure 7). The grayscale values of CBCT were converted to Hounsfield units with a mathematical formula HU = −61.098 + 1.178 × grayscale(12). The mean Hounsfield units of stage A were 521.42 +/- 16.95 HU implying that it belongs to the D3 category of Misch's classification of bone density suggesting that it consisted of thin porous cortical and trabecular bone (Table 5). Similarly, stage B showed a mean of 936.76+/-11.24 HU implying that it belongs to the D2 category of Misch's classification of bone density suggestive of porous cortical bone and dense trabecular bone. Stage C showed a mean of 1351.40+/- 135.91 HU implying a borderline bone density D1 and D2 of Misch's classification of bone density. Stages D and E showed a mean of 1575.04 +/- 135.91 HU and 1698.49 +/- 70.02 HU belongs to the D1 category of Misch's classification of bone density suggestive of dense cortical bone(13)(14). The intra-operator reliability was assessed by Cronbach's Alpha test and it showed an excellent internal consistency. The inter-operator reliability was assessed by Kappa statistics and it showed a fair agreement between the two observers.

Chronological age is unreliable for determining the maturational stage of the maxillary sutures(15). Franchi et al in his study assessed the radiodensity in the midpalatal suture using Hounsfield quantitative scale in low dose computed tomography scans(16). Exposing young patients to computed tomography scans for diagnosis and treatment planning is unjustified. Korbmacher et al. in his study assessed palatal suture maturation via micro-CT scanning in cadaver specimens, but their applicability of results to clinical practice is questionable(17). Sumer et al. used ultrasound to assess sutural mineralization (18). The relevancy of using ultrasound to evaluate the cortical bone and suture evaluation before the maxillary expansion is doubtful. The study by Angelieri et al. is a subjective assessment of palatal suture maturity and further studies to validate the classification is recommended(2). Chanchala et al. in her study reported that CBCT-based prediction of stages of mid-palatal suture maturation related to the age and gender by Fernanda Angelieri is valid among the Indian population(19). The limitation of the study was the use of CT images instead of CBCT scans. However, the mean age of males and females categorized according to Angelieri's classification of palatal suture maturation of Chanchala et al. are similar to our study. Our cone-beam computed tomography study results suggest that as the age increases, the grayscale value also increases. Since unreliability is often found in mid palatal suture maturation in patients, chronological age cannot be depended on to infer the outcomes of the treatment. Thus, a separate estimation of midpalatal suture is essential before the treatment.

It is difficult to compare the MPDS taken from different CBCT machines due to low standardization or to depend on values to shift from RME to MARPE/ SARPE. Morphological maturation stage D with grayscale value 1389 plays an important role in deciding the treatment modality for a patient as stage C denotes partial closure of midpalatal suture, whereMARPE can be given for transverse expansion and stage E denotes complete closure, where non-invasive technique MARPE with a cortical puncture(20) or SARPE can be advised.

Angelieri et al proposed five maturational stages of the midpalatal suture: Stage A, straight high-density sutural line with no or little interdigitation; Stage B, the scalloped appearance of the high-density suture line; Stage C, two parallel scalloped high-density lines that are closer to each other and are separated in some areas by small low-density spaces; Stage D, fusion completed n the palatine bone with no evidence of a suture; and stage E, complete anterior fusion in the maxilla. (3). He hypothesized that RME treatment is successful in A and B stages, and it is also successful in stage C with less skeletal effects. The differences in MPDS between these stages, found in the current study, may approve the reliability of Angelieri et al classification to choose between RME and MARPE to make a clinical decision.

Angelieri et al. classification requires a lot of training to reach an acceptable level of ability to distinguish between the five stages. The direct comparison of the grayscale value between CBCT scanners is not possible (21);thus, absolute values of density of mid palatal suture could not be depended on to assess the maturation stage of midpalatal suture or to choose between RME and SARPE. Hounsfield Unit (HU) can be derived from the grey levels in dental CBCT scanners using linear attenuation coefficients as an intermediate step(22,23).Grouping of CBCT according to the morphologic classification stages of the mid palatal suture by Angelieri et al was challenging, especially to identify the various stages was one of the limitations of the study. Another limitation was that the grayscale values varied with different CBCT machines. Further studies on pretreatment and post-treatment CBCT scans of patients with posterior crossbite must be assessed to know the clinical relevance of mid palatal suture density measurement using grayscale values with large sample size and to find such grayscale values might validate mid palatal sutural density as an objective, quantitative, simpler, and overall, more useful indicator. The limitations of the present study are that it is a retrospective cross-sectional unicentric study done on a smaller section of the population. Further research is required to prove the utility of grayscale in diagnosis and its relation with Hounsfield units of CT.

5. CONCLUSION

The statistical significance between the maturational stages of the maxillary suture with the grayscale values obtained in the CBCT implies that it can be used as a predictor to assess palatal suture ossification during diagnosis and treatment planning. This would help as an additional supplemental aid to a clinician interpreting mid palatal sutural density. One of the major advantages of assessing with the grayscale is that most orthodontic patients are subjected only to CBCT where the provision for checking the Hounsfield unit is not available, therefore this method would prove to be an alternate and reliable tool.

6. ACKNOWLEDGMENT

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7. DECLARATION OF INTEREST STATEMENT

The Author(s) declare(s) that there is no conflict of interest.

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9. APPENDICES

Abbreviations

CBCT: Cone beam computed tomography

MARPE: Miniscrew assisted rapid palatal expansion

SARPE: surgical assisted rapid palatal expansion

MPS: Midpalatal suture

RME: rapid maxillary expansion

MPDS: mid palatal density of the suture

SPSS: statistical package for the social sciences

A.M: Akshay Mohan

S.K: Shanthasundari K.K

Mid palatal suture classification	Mean	Standard deviation	Standard error	p-value
A	494.50	37.47	26.50	0.00
B	870	42.32	11.31	
C	1199.07	97.52	26.06	
D	1388.92	167.24	44.69	
E	1493.71	111.31	29.74	

Table 1: The table depicts the mean, standard deviation, standard error, and significance of grayscale values.

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Morphological maturation stage	Males		Females	
	Mean (Years)	SD (Years)	Mean (Years)	SD (Years)
A	5.5	0.6	-	-
B	12.42	1.59	13.42	0.90
C	15.28	3.95	17.28	3.49
D	17.71	2.81	14.71	1.03
E	23.85	2.84	22.14	3.68

Table 2 : The mean age and standard deviation of the subjects included in the study.

Morphological maturation stage	Sample size	Males	Females
A	2	2	0
B	14	5	9
C	14	8	6
D	14	9	5
E	14	10	4

Table 3: Sample size distribution of morphological maturation stage among males and females.

Mid palatal maturation stage	Grayscale units		Hounsfield	
	Mean	SD	Mean	SD
A	494.50	37.47	521.42	16.95
B	870	42.32	963.76	11.24
C	1199.07	97.52	1351.40	53.7

D	1388.92	167.24	1575.04	135.91
E	1493.71	111.31	1698.49	70.02

Table 4: The table depicts the mean, standard deviation of grayscale values and its corresponding converted Hounsfield units (HU).

Mid palatal maturation stage	**Hounsfield (HU)**		**Bone Classes**
	Mean	**SD**	
A	521.42	16.95	D3
B	963.76	11.24	D2
C	1351.40	53.7	D1
D	1575.04	135.91	D1
E	1698.49	70.02	D1

Table 5: The table depicts the mean and standard deviation of Hounsfield units(HU), and bone density according to Misch's classification(13).

Figure caption:

1. Figure 1: Gray scale values of stage B of mid palatal suture maturation on CBCT.
2. Figure 2: Gray scale values of stage C of mid palatal suture maturation on CBCT.
3. Figure 3: Gray scale values of stage D of mid palatal suture maturation on CBCT.
4. Figure 4: Gray scale values of stage E of mid palatal suture maturation on CBCT
5. Figure 5: The graph represents the mean gray scale values of groups(stages A-E) of midpalatal suture classification.
6. Figure 6: The bar chart represents the mean and standard deviation of gray scale values of groups(stages A-E) of midpalatal suture classification.
7. Figure 7: Scatter plot of correlation between age and gray scale value. Pearson correlation test was done to assess the correlation between age and gray scale value; r =0.599 , p=0.00

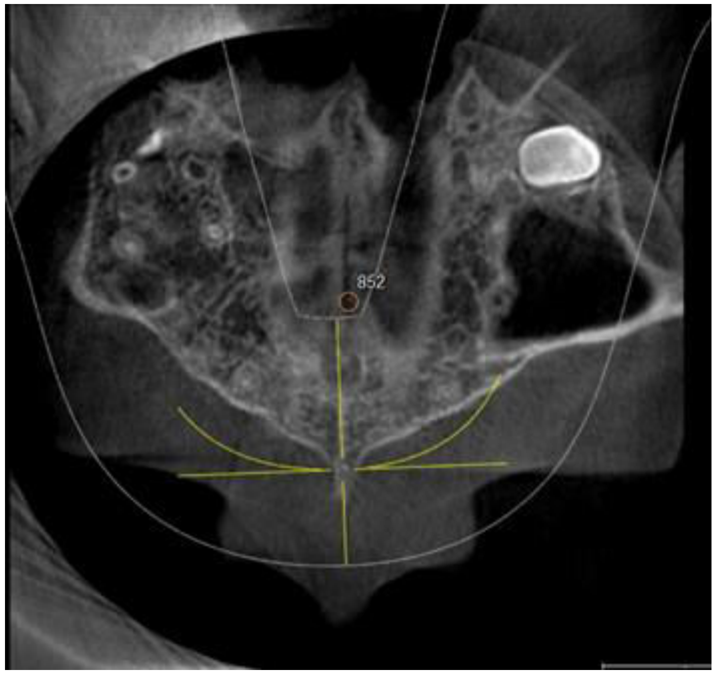

Figure 1: Gray scale values of stage B of mid palatal suture maturation on CBCT.

Figure 2: Gray scale values of stage C of mid palatal suture maturation on CBCT.

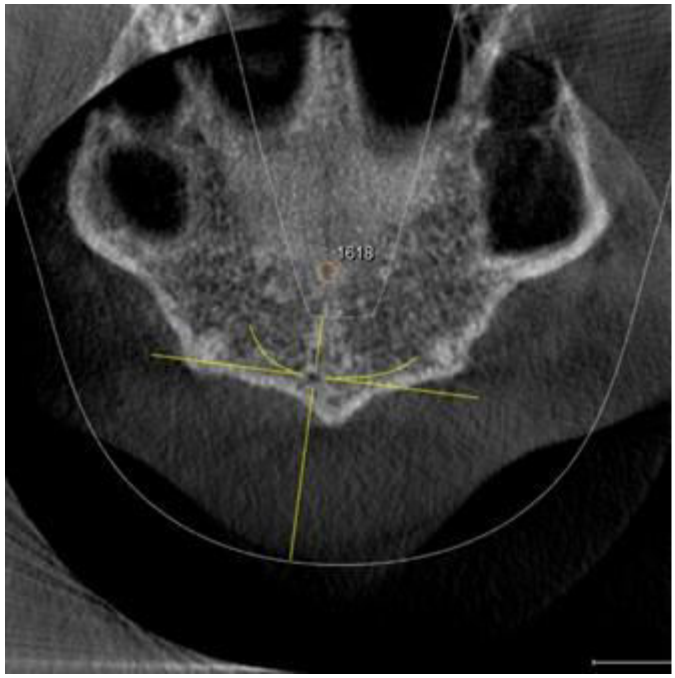

Figure 3: Gray scale values of stage D of mid palatal suture maturation on CBCT.

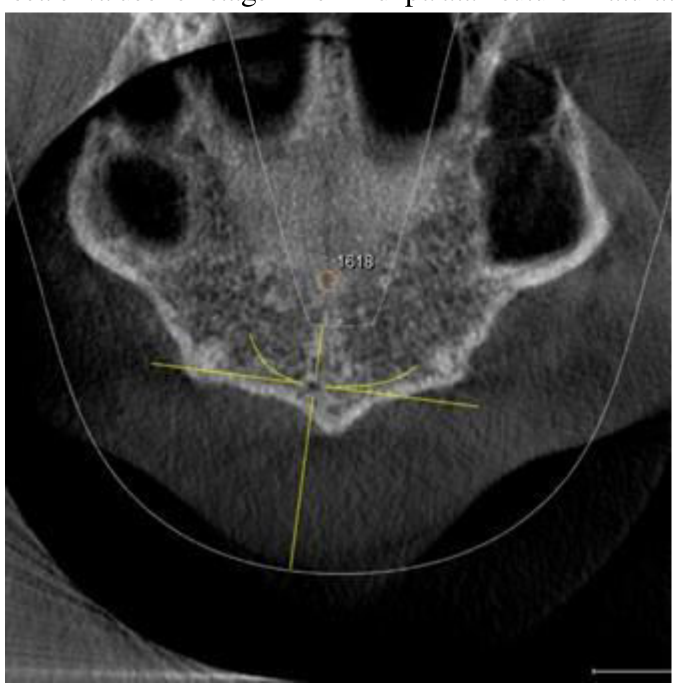

Figure 4: Gray scale values of stage E of mid palatal suture maturation on CBCT

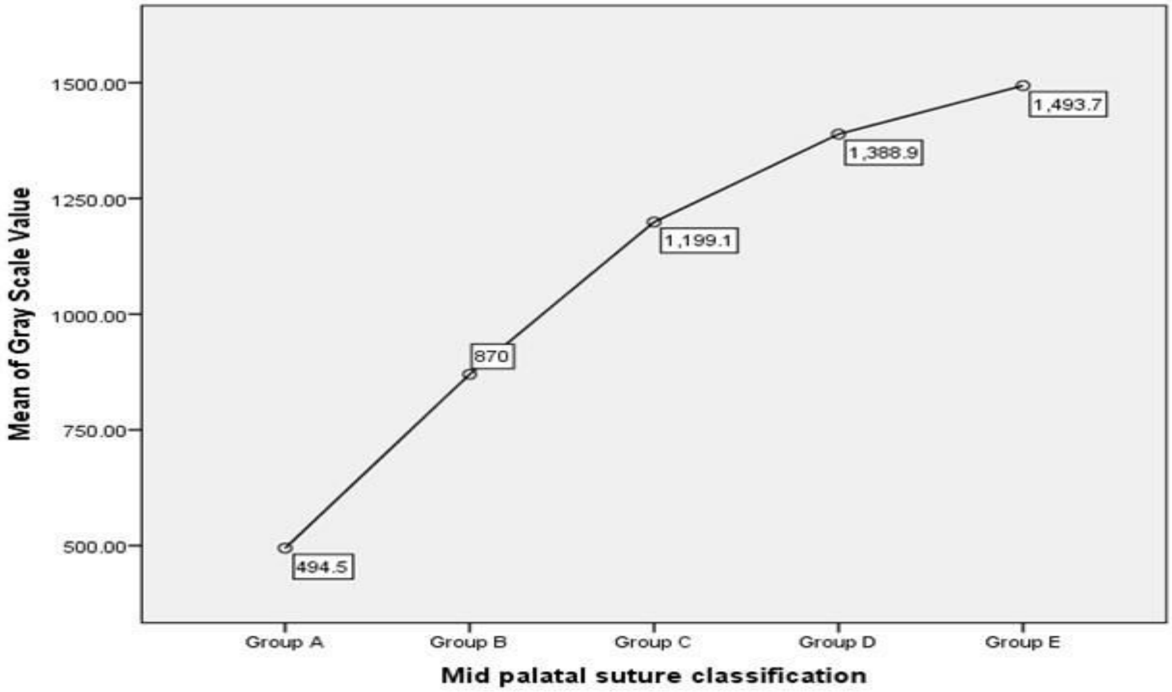

Figure 5: The graph represents the mean gray scale values of groups (stages A-E) of midpalatal suture classification.

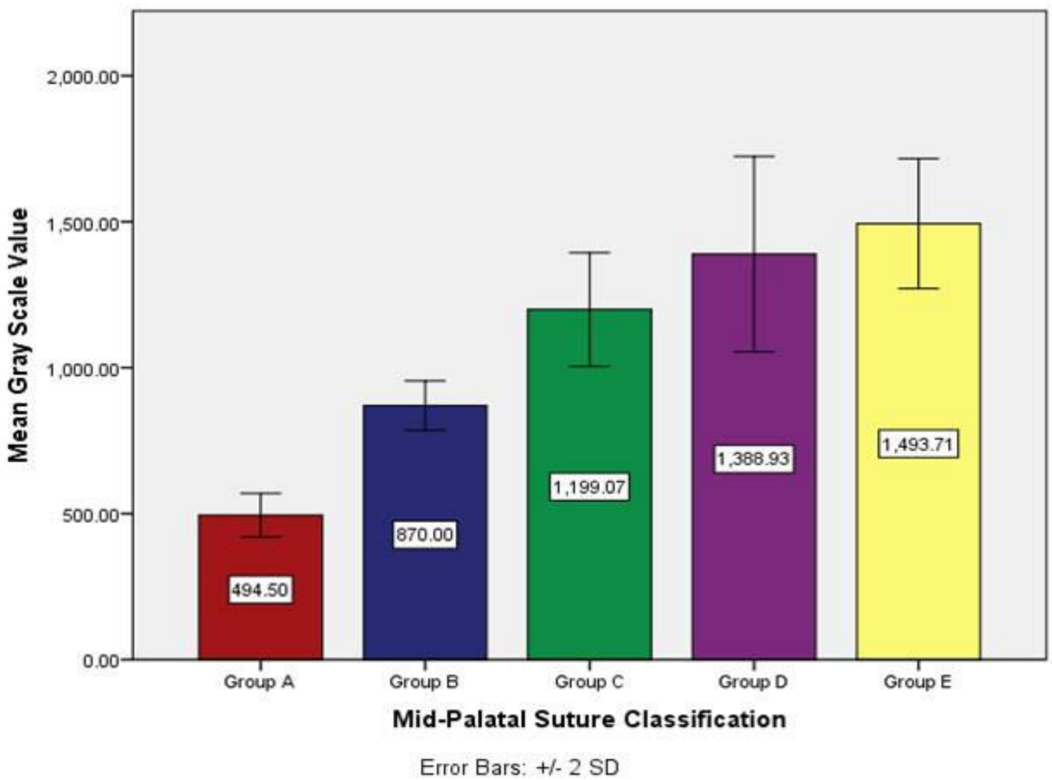

Figure 6: The bar chart represents the mean and standard deviation of gray scale values of groups (stages A-E) of midpalatal suture classification.

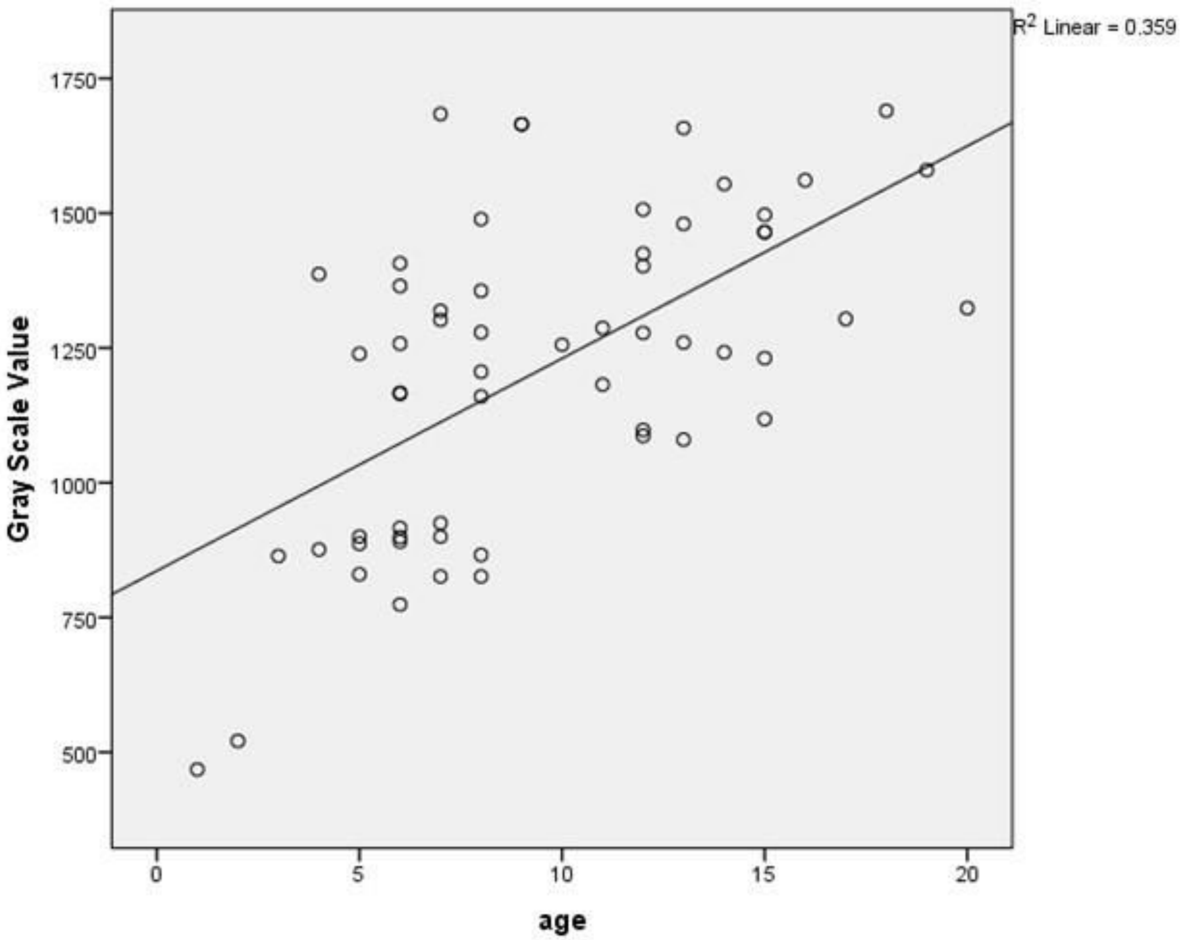

Figure 7: Scatter plot of correlation between age and gray scale value. Pearson correlation test was done to assess the correlation between age and gray scale value; r =0.599, p=0.00