TITLE PAGE

Title: The potential of odontometric measurements for sex and age determination through cast analysis in the North Indian population

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Declarations

Ethics approval and consent to participate: This study protocol was submitted to the Institutional ethical committee of King George's Medical University Institutional Ethics committee for evaluation and clearance. The ethical clearance number was obtained via Letter No.**2060/Ethics/2023**, (REGISTRATION NUMBER: ECR/262/Inst/UP/2013/RR-19). This article does not contain any studies with animals performed by any of the authors. The informed consent was waived off due to the retrospective nature of the study.

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Author's contributions:

Dr Ayushi Jain	-	Methodology, Resources, Data curation, Formal analysis, Writing original draft
Dr Priya Devi	-	Conceptualization, Resources, Validation, Supervision, Review of manuscript.
Dr Shalini Gupta	-	Conceptualization, Resources, Data curation, Validation, Supervision, Review and Editing of manuscript.
Dr Rakesh Dewan	-	Validation, Supervision, Review and Editing of manuscript
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ABSTRACT:

Objectives: Various dental morphological features, as well as odontometric parameters, have been used for gender determination such as mandibular and maxillary canine indices, mandibular canine dimensions, maxillary canine dimension, maxillary first molar dimensions, and the cumulative dimension of all teeth. However, the results are variable in the studies. This study aims to evaluate the parameters mentioned above along with the inclusion of more odontometric parameters for age and sex estimation.

Methods: In this study, some principal maxillary and mandibular odontometric measurements were considered for 360 individuals (190 males and 170 females) and recorded using a digital vernier caliper from the casts. The parameters were correlated with the age and gender of individuals with the help of ANOVA and independent t-test respectively.

Results: Using discriminant statistical analysis, the present data were analyzed. This study concludes that intercanine and intermolar width for the second molar was higher in males than females. In contrast, all other parameters have a comparable mean in both samples. With the help of the Pearson correlation, MDR6 was found to be significantly associated ($p<0.05$) with age. Additionally, univariate analysis was employed to evaluate age prediction for both the maxillary and mandibular cases.

Conclusion: This study concludes that odontometric measurements could be helpful in the identification of an individual by estimating age and gender. In the maxillary and mandibular arches, it was discovered that females had greater intercanine and intermolar widths for the second molar than males. Additionally, an individual's estimated age may be accurately predicted by measuring the mesiodistal width of their right first molar.

Keywords: Dimorphism, Multivariate, Univariate, Dental casts, Mesiobuccal Distolingual, Odontometric, discriminant function

INTRODUCTION

Forensic odontology is the sub-branch of dentistry and one of the disciples of forensic science, which involves thorough holistic management, examination, evaluation, and presentation of dental evidence in criminal and civil matters and serves the purpose of justice. The primary evidence and expert opinion in this area mainly rely on teeth and the determination of sex, age, and identity of the individual to whom the teeth belong (1).

It appears that the basic conceptual underpinnings of odontology and the conventional focus on diagnosis and treatment planning are about to undergo a paradigm shift. Odontologists are increasingly becoming involved in forensic science studies worldwide and are crucial in determining age and identifying individuals (2). Teeth are the hardest and chemically most stable part of the human body, thus rendering it to be an indispensable tool in anthropological, genetic, ontological, and forensic investigations (3). Currently, multiple studies established the role and function of the tooth in forensic science mainly focusing on age determination and post-mortem interval. The age can be estimated by examination of the fontanelles in infancy, eruption and sequence of eruption, shedding pattern of teeth in childhood, Cameriere's and Demirjian's methods of age estimation (25, 26), etc., and the ethnicity by the tooth size and anomalies (4). Similarly, multiple studies have shown the correlation of the tooth morphological features to the molecular matter degradation pattern for the estimation of post-mortem interval. The plenty of studies in these fields have led researchers to determine the correlation of teeth with sex determination (5).

Anthropologists still hold little insight into the perspicacity of the sexual identification of immature skeletal remains. Under these circumstances, recent studies are now laying the foundation of the odontometric features of the teeth to determine the gender of the individual through dental casts. Various dental morphological features, as well as odontometric parameters, have been used for gender determination such as mandibular and maxillary canine indices, mandibular canine dimensions, maxillary canine dimension, maxillary first molar dimensions, and the cumulative dimension of all teeth. Also, the measurement of mesiodistal and buccolingual dimensions of the tooth is being used to differentiate the sex of an individual. Moreover, canine shows univariate sexual dimorphism and can be accurately determined from maxillary and mandibular canine and 2nd molar in 77% of cases (7). The canine is considered to be least exposed to diseases, injuries, and abrasions, and for sexual dimorphism, the mandibular canine is believed to be the best tooth among all (8). Despite being reliable, the mandibular canine index (CI) has its limitations as the mandible is a single bone that is not directly attached to the skull and poses increased chances of trauma or damage.

An experimental study conducted on plaster models by Singh *et al* observed that there is a fair deviation ($P < 0.05$) between left and right canine width and right and left MCI within males and females (9). A similar study was carried out with a 75% accuracy rate for the age group of 17–25 years in the population of central India, and the results showed that the left mandibular canine teeth had slightly higher sexual dimorphism (10). The above studies assist in the determination of sex and the basis for anthropologic and forensic investigations.

A study conducted by Kiran *et al* indicates that the Discriminant canine index (DCI) - a novel technique and an alternative for MCI index, depicted an increase in the mesiodistal width of canines in males (7.21 ± 0.45 mm) whereas females depicted (6.77 ± 0.29 mm) with an overall

accuracy of 72.5%. The DCI value also talks about the gender possibility like (DCI > 0 for male) while (DCI < 0 for female) (11). Recently, a study conducted by Priya *et al* showed that there is a statistically insignificant variation in crown length and mesiodistal width of both left and right mandibular canines when studied, analyzed, and equated within the same individual (12). However, in our knowledge, this is the first study to attempt correlating the odontometric parameters with the age groups. In this string**,** this study seeks to evaluate the probability of determining gender and age using odontometric measurements and to compare the efficacy of these parameters with each other.

MATERIALS AND METHOD

The study was accomplished in the Department of Oral Pathology, Microbiology & Forensic Odontology after obtaining the institutional research committee and university ethical clearance. The study sample comprised patients of the North Indian population of the age of the study population with their written consent. A base sample of 360 individuals (190 males and 170 females) was collected. This age group was particularly selected as dimensional changes due to attrition and abrasion are minimal in them.

Patients were selected based on inclusion criteria as follows:

- Periodontal healthy teeth
- Non-carious teeth +
- Non-attrite and intact teeth
- Satisfactorily aligned mandibular teeth.

Exclusion criteria: patients were excluded from the study as per the following condition:

- Any trauma to canine teeth

- History of treatment and bony pathology.

After obtaining the consent, the impression of both the maxillary and mandibular arch was taken using irreversible hydrocolloid and poured using Type III dental stone immediately to avoid any distortion. The maxillary and mandibular cast thus reconstructed were used as study models and employed for analysis. All the measurements carried on the casts were executed with the help of digital calipers with a resolution of 0.01 mm by a single observer for easy and universal replicability.

The following measurements were taken for the evaluation:

Canine width (CR3 and CL3): The mesiodistal dimension of the maxillary and mandibular canine (CMD) was measured as the distance between the mesial and distal contact points for both right and left side.

Inter-canine width (ICW): It was measured by placing the beaks of the digital vernier caliper at the cusp tips of the canine, and the linear distance between the left and right canine was measured for both maxillary and mandibular canine.

Intermolar width (IMW6 and IMW7): The distance between the mesiobuccal cusp tips of both the right and left maxillary and mandibular first and second molars.

Buccolingual width (BLR6 and BLL6): The maximum width between the buccal and lingual surfaces perpendicular to the mesiodistal size of both the right and left first molar of the maxilla and mandible.

Mesiodistal width (MDR6 and MDL6): The distance between the mesial and distal points of contact of the maxillary and mandibular first molar, measured with the caliper placed perpendicular to the occlusal surface.

Mesiobucco-distolingual width (MBDLR6 and MBDLL6): The distance between the tip of the mesiobuccal cusp and the distolingual cusp of both the maxillary and mandibular first molar.

Distobucco-mesiolingual width (DBMLR6 and DBMLL6): The distance between the tip of the distobuccal cusp and the mesiolingual cusp of both the maxillary and mandibular first molar.

All the parameters were measured by two professional dentists with a good experience in the anatomy of the tooth structure. The measurements were tabulated in Microsoft Excel. The parameters were correlated with the age and gender of individuals with the help of ANOVA and independent t-test respectively. Additionally, with the help of univariate analysis, the linear regression was also evaluated for age prediction for both the maxillary and mandibular cases.

RESULTS

The data on teeth measurements of mandibular casts was treated statistically using the standard program of IBM SPSS 29 (International Business Machines Statistical Package for Social Sciences) for descriptive statistics, t-test, and univariate discriminant function analysis. Table 1 describes the association of all the given parameters with the gender of the sampled individual with the help of independent t-test.

Table 1: Descriptive measures of all the odontometric parameters according to the gender of an individual using two sample independent t-test (P<0.05 is considered significant)			
	Gender		
	Male(n=190)	Female(n=170)	
	Mean ± SD	Mean ± SD	p value
CR3	0.7±0.11	0.71±0.12	0.789
CL3	0.71±0.12	0.7±0.12	0.777
ICW	3.11±0.6	3.06±0.53	0.474
IMW6	4.26±0.52	4.27±0.49	0.96
IMW7	4.82±0.52	4.78±0.56	0.475
BLR6	1.04±0.12	1.04±0.13	0.402
BLL6	1.04±0.13	1.02±0.15	0.135
MDR6	0.99±0.13	0.97±0.13	0.19
MDL6	0.99±0.13	0.97±0.12	0.089
MBDLR6	1.07±0.18	1.05±0.17	0.235
MBDLL6	1.07±0.2	1.04±0.19	0.24
DBMLR6	0.99±0.18	0.97±0.2	0.249
DBMLL6	0.99±0.19	0.95±0.21	0.088

With the results, it can be seen that both ICW and IMW for second molar were found to be higher in the males as compared to females whereas all other parameters have a comparable mean in both the male and female samples. However, no parameters were found to be correlated statistically significantly with the gender of the individual.

While employing the one-way ANOVA for the association of age with all the odontometric measurements, no parameter was found to be significantly associated ($p<0.05$) (Table 2).

Table 2: Descriptive measures for different categories of age with the various odontometric parameters using one way ANOVA test (P<0.05 is considered significant)						
Parameters	**10 - 19 years**	**20 -29 years**	**30 - 39 years**	**40 - 49 years**	**> 49 years**	**P value**
CR3	0.7±0.1	0.71±0.12	0.69±0.1	0.82±0.16	0.71±0	0.385
CL3	0.69±0.09	0.71±0.14	0.7±0.1	0.81±0.17	0.7±0	0.504
ICW	3.11±0.59	3.08±0.56	3.06±0.56	3.03±0.59	3.19±0	0.987
IMW6	4.28±0.48	4.25±0.49	4.33±0.64	4.07±0.4	4.43±0	0.817
IMW7	4.81±0.53	4.79±0.54	4.86±0.61	4.63±0.55	5.42±0	0.678
BLR6	1.04±0.14	1.04±0.13	1.03±0.1	1.07±0.21	1.06±0	0.993
BLL6	1.04±0.13	1.03±0.15	1.04±0.11	1.06±0.2	1.03±0	0.944
MDR6	0.96±0.1	0.98±0.13	0.98±0.16	1.04±0.06	0.98±0	0.732
MDL6	0.97±0.11	0.98±0.12	0.96±0.16	1±0.09	0.95±0	0.766
MBDLR6	1.07±0.18	1.05±0.18	1.04±0.19	1.14±0.14	1.18±0	0.704
MBDLL6	1.07±0.19	1.05±0.2	1.04±0.19	1.1±0.17	1.25±0	0.741
DBMLR6	0.98±0.18	0.98±0.19	0.97±0.23	1.02±0.16	1.04±0	0.979
DBMLL6	0.98±0.19	0.97±0.2	0.94±0.23	1.03±0.17	1.05±0	0.753

Along with it the correlation of the odontometric parameters was also correlated with age with the help of the Pearson correlation and only MDR6 was found to be significantly associated ($p<0.05$). With the help of univariate analysis, the linear regression was also evaluated for age prediction for both the maxillary and mandibular cases (Table 3).

Table 3(A): Univariate analysis for age prediction for maxilla cases using linear regression				
	Formula	**r square**	**SE**	**p value**
CR3	Age = 19.359 + (5.398*CR3)	0.011	6.33	0.179
CL3	Age = 18.273 + (6.901*CL3)	0.016	6.33	0.105
ICW	Age = 22.485 + (0.217 * ICW)	0	6.384	0.818
IMW6	Age = 20.760 + (0.561*IMW6)	0.002	6.362	0.557
IMW7	Age = 21.485 + (0.344 * IMW7)	0.001	6.398	0.681
BLR6	Age = 25.315 + (-2.03 * BLR6)	0.002	6.36	0.609
BLL6	Age = 18.70 + (4.31 * BLL6)	0.007	6.347	0.289
MDR6	Age = 15.41 + (8.07 * MDR6)	0.022	6.299	0.059
MDL6	Age = 23.314 + (-0.130 * MDL6)	0	6.36	0.974
MBDLR6	Age = 21.033 + (2.056 * MBDLR6)	0.003	6.359	0.482
MBDLL6	Age = 21.06 + (1.977 * MBDLL6)	0.004	6.358	0.45
DBMLR6	Age = 23.05 + (0.139 * DBMLR6)	0	6.36	0.959
DBMLL6	Age = 23.03 + (0.163 * DBMLL6)	0	6.36	0.947
Table 3(B): Univariate analysis for age prediction for mandible cases using linear regression				
	Formula	**r square**	**SE**	**p value**
CR3	Age = 23.587 + (-0.146 * CR3)	0	6.357	0.973
CL3	Age = 22.4 + (1.47 * CL3)	0.001	6.322	0.684
ICW	Age = 25.55 + (-0.689 * ICW)	0.04	6.312	0.373
IMW6	Age = 26.26 + (-0.66 * IMW6)	0.003	6.31	0.48
IMW7	Age = 26.58 + (-0.58 * IMW7)	0.002	6.319	0.543
BLR6	Age = 24.39 + (-0.887 * BLR6)	0	6.32	0.805
BLL6	Age = 27.67 + (-4.08 * BLL6)	0.01	6.24	0.166
MDR6	Age = 20.32 + (3.27 * MDR6)	0.005	6.3	0.327
MDL6	Age = 21.95 + (1.54 * MDL6)	0.01	6.32	0.676
MBDLR6	Age = 26.05 + (-2.42 * MBDLR6)	0.005	6.3	0.322
MBDLL6	Age = 26.46 + (-2.83 * MBDLL6)	0.008	6.301	0.222
DBMLR6	Age = 23.13 + (0.345 * DBMLR6)	0	6.32	0.882
DBMLL6	Age = 25.33 + (-1.896 * DBMLL6)	0.004	6.31	0.41

Additionally, the measurements were compared for both the maxilla and mandible, and it was found that ICW (p=0.022), IMW6 (p=0.025), BLL6 (p=0.047), and MDR6 (p=0.044) were significantly associated with the arch.

DISCUSSION

In forensics, individualization or gender identification is determined particularly from bones, and skeletal remains but, teeth play a major role in this field due to resilience to destruction, which depends on the availability and condition of bones. The sex identification is mainly based on the non-metric and metric dental traits using dental features. The metric traits are the tooth dimensions, specifically odontometrics. These odontometric parameters are easy to measure as well as reliable and inexpensive conduct, which can be studied for the determination of sex/gender in a large population, and also formulates statistical analysis and compares within the samples and former literature review. However, the limitation of conducting these types of studies is the non-availability of the complete skeleton. (12)

In this study, the comparison of mesiodistal widths of maxillary and mandibular canines between males and females was found to be statistically insignificant as shown in Table 1. The reference to this does not conform with the previous study by Ghose *et al* 1979, Garn *et al* 1967, Nair et al.1999, Yadav *et al* 2002 and Hemani *et al* 2008 who found a significant association [14,15,16,18,21]. However, in most of the measurements of male samples, the data shows slightly higher values in Inter-canine width and Inter-molar width in cases of second molar, and these values were considered as an exception as all other parameters were more or less similar in both genders. These findings are similar to Muller *et al* 2001 (23), Yadav *et al* 2002 (18), Anderson *et al* 1973 (22), and Kaushal *et al* 2003 (17). The reason for the differences in inter-canine width may be because of the late cessation of growth in males as compared to females. Also, a study conducted by Garn *et al* 1967 displayed the greatest sexual dimorphism differences in the mesiodistal width of the mandibular canine. In this string, Kiran *et al* conducted a study that shows that higher sexual dimorphism was found in the right mandibular canines (6.84%) when compared with the left

mandibular canines (6.17%) in terms of mesiodistal width while the left mandibular canine was found to be the most dimorphic in terms of buccolingual dimensions among the canine (19,20). To determine the gender from odontometric variables, some previous studies by Sharma *et al* reported that the univariate discriminant function analysis reveals the mesiobuccal distolingual distance (MBDL) dimension of the first molar of maxilla showed 67.2% accuracy while the distobuccal mesiolingual distance (DBML) dimension of a first molar of mandibular shows 73.8% of accuracy (24).

To our knowledge, this is the first study to attempt correlating the odontometric parameters with the age groups. It was discovered that while comparing all the odontometric measurements, no parameter was found to be significantly associated with the age of an individual ($p<0.05$). Along with it the correlation of the odontometric parameters was also correlated with age with the help of the Pearson correlation and only MDR6 was found to be significantly associated ($p<0.05$). With the help of univariate analysis, the linear regression was also evaluated for age prediction for both the maxillary and mandibular cases (Table 5). However, we found that for both the maxilla and mandible, ICW, IMW6, BLL6, and MDR6 were significantly associated with the arch ($p < 0.05$).

The limitation of the study was the unequal distribution of the male and female samples. However, the strength of the research is the inclusion of all the important parameters mentioned in the literature and correlating them with the age and gender.

CONCLUSION

This study concludes that the odontometric measurements could be helpful in the identification of an individual by estimating age and gender. Both the intercanine width and the intermolar width for the second molar in both the maxillary and mandibular arch were found to be more in the

females as compared to males. Also, the mesiodistal width of the right first molar may be a good predictor for the age estimation in an individual.

Declarations

Ethics approval and consent to participate: This study protocol was submitted to the Institutional ethical committee of King George's Medical University Institutional Ethics committee for evaluation and clearance. The ethical clearance number was obtained via Letter No.**2060/Ethics/2023**, (REGISTRATION NUMBER: ECR/262/Inst/UP/2013/RR-19). This article does not contain any studies with animals performed by any of the authors. The informed consent was waived off due to the retrospective nature of the study.

Consent for publication: Not Applicable

Availability of data and material: The present retrospective radio morphometric analysis was performed in the Department of Oral Pathology & Microbiology, KGMU, Lucknow

Conflict of interest: We have no conflict of interest to declare

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Author's contributions: Authors testify that all persons designated as authors qualify for authorship and have checked the article for plagiarism. If plagiarism is detected, all authors will be held equally responsible and will bear the resulting sanctions imposed by the journal thereafter.

AJ designed the methodology, provided research materials, curated data, did the formal analysis, and wrote the original draft. PD did the conceptualization, and validation, and reviewed the manuscript. SG did the conceptualization, curated and validated the data, and reviewed and

edited the manuscript. RD validated, supervised, reviewed, and edited the manuscript. PS validated, supervised, reviewed, and edited the manuscript**.**

All authors have critically reviewed and approved the final draft and are responsible for the content and similarity index of the manuscript.

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LEGENDS:

Table 1: Descriptive measures of all the odontometric parameters according to the gender of an individual using two sample independent t-test ($P<0.05$ is considered significant)

Table 2: Descriptive measures for different categories of age with the various odontometric parameters using one way ANOVA test ($P<0.05$ is considered significant)

Table 3 (A): Univariate analysis for age prediction for maxilla cases using linear regression; **(B)** Univariate analysis for age prediction for mandible cases using linear regression

Figure 1: Simple bar graph representing the odontometric measurements (A) Mean values of CR3, CL3, ICW, IMW6, IMW7 and BLR6 on the y-axis by the sex of the individual on the x-axis (male and female); (B) Mean values of BLL6, MDR6, MDL6, MBDLR6, MBLL6, DBMLR6 and DBMLL6 on the y-axis by the sex of the individual on the x-axis (male and female)

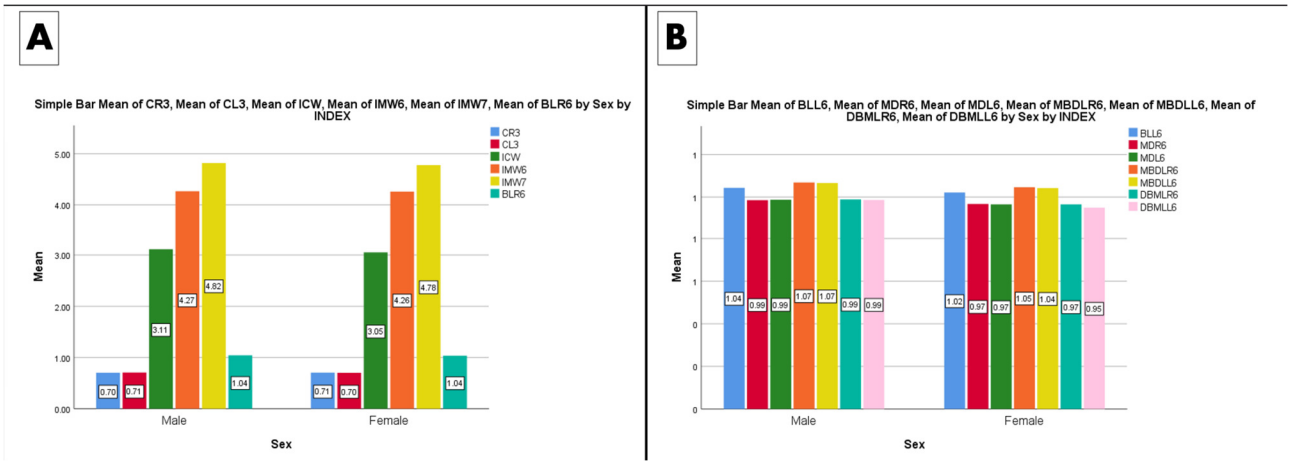
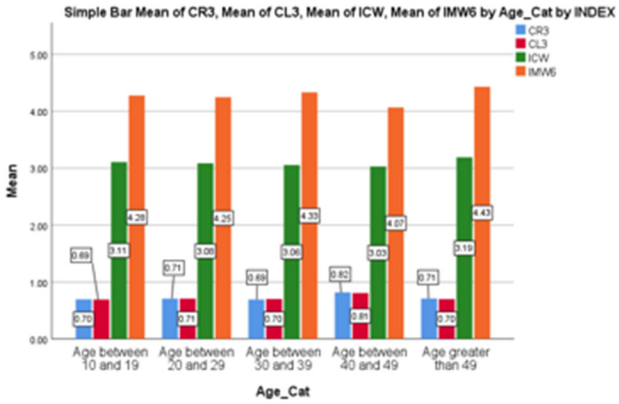
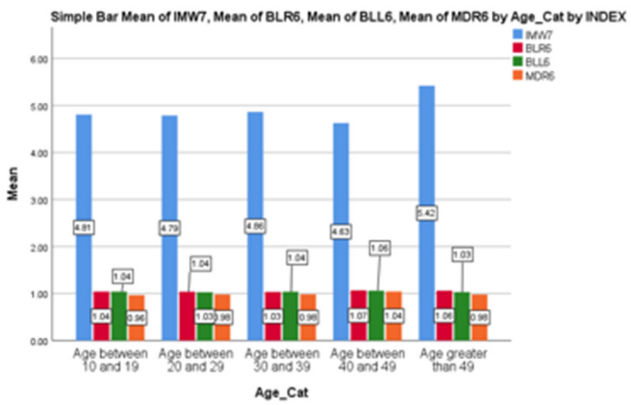


Figure 2: Simple bar graph representing the odontometric measurements on the x-axis with the age categories on the y-axis (10-19 years, 20-29 y years, 30-39 years, 40-49 years, and >49 years) (A) Mean values of CR3, CL3, ICW and IMW6; (B) Mean values of IMW7, BLR6, BLL6 and MDR6; (C) Mean values of MDL6, MBDLR6, MBLL6, DBMLR6 and DBMLL6

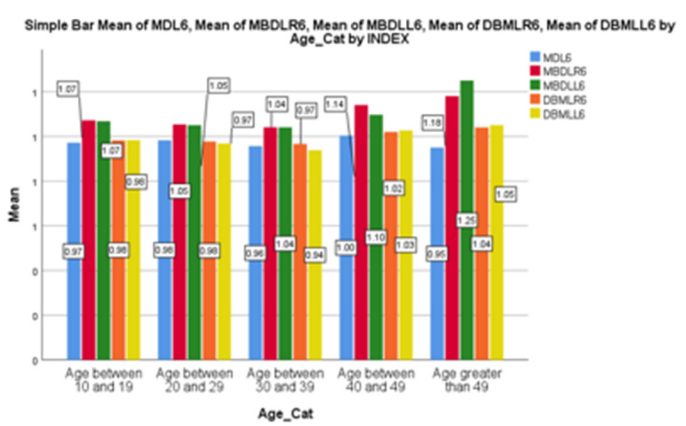
A


Simple Bar Mean of CR3, Mean of CL3, Mean of ICW, Mean of IMW6 by Age_Cat by INDEX
CR3
CL3
ICW
IMW6
Mean
Age between 10 and 19
Age between 20 and 29
Age between 30 and 39
Age between 40 and 49
Age greater than 49
Age_Cat

B


Simple Bar Mean of IMW7, Mean of BLR6, Mean of BLL6, Mean of MDR6 by Age_Cat by INDEX
IMW7
BLR6
BLL6
MDR6
Mean
Age between 10 and 19
Age between 20 and 29
Age between 30 and 39
Age between 40 and 49
Age greater than 49
Age_Cat

C


Simple Bar Mean of MDL6, Mean of MBDLR6, Mean of MBDLL6, Mean of DBMLR6, Mean of DBMLL6 by Age_Cat by INDEX
MDL6
MBDLR6
MBDLL6
DBMLR6
DBMLL6
Mean
Age between 10 and 19
Age between 20 and 29
Age between 30 and 39
Age between 40 and 49
Age greater than 49
Age_Cat