Journal of Neonatal Surgery
ISSN(Online): 2226-0439
Vol. 14, Issue 32s (2025)
https://www.jneonatalsurg.com

OPEN ACCESS

Anatomical Parameters of The Nasolacrimal Duct in Children {Up West} Measured with Computed Tomography

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Cite this paper as: Nikita Upadhyay, Amit Bisht, (2025) Anatomical Parameters of The Nasolacrimal Duct in Children {Up West} Measured with Computed Tomography. *Journal of Neonatal Surgery*, 14 (32s), 572-595.

ABSTRACT

The nasolacrimal duct (NLD) plays a crucial role in tear drainage from the ocular surface to the nasal cavity, and its anatomical variations in children are of significant clinical relevance, particularly in the context of congenital nasolacrimal duct obstruction (CNLDO). This study aims to evaluate the normative anatomical parameters of the NLD in the pediatric population using high-resolution imaging modalities, including multidetector computed tomography (MDCT) and magnetic resonance imaging (MRI). Key parameters assessed include NLD length, diameter, angulation, and the morphology of the nasolacrimal canal.

A retrospective analysis was conducted on imaging data from paediatric patients aged 0–20 years who underwent head CT scans for non-lacrimal indications. The NLD was visualized in axial and sagittal planes, and measurements were stratified by age and gender. The study revealed that NLD length and diameter increased progressively with age, with statistically significant differences noted between age groups. No significant gender differences were found in most parameters. The angle of the NLD relative to the nasal floor was also found to vary slightly with age, which may potentially influence tear flow dynamics.

These findings establish normative reference values for NLD dimensions in children and enhance understanding of age-related anatomical development. The data have important implications for the diagnosis and management of CNLDO and for planning pediatric dacryocystorhinostomy (DCR) procedures. Further prospective studies with larger cohorts are recommended to validate these findings and explore ethnic or population-based variations.

Keywords: *Nasolacrimal duct (NLD), Congenital nasolacrimal duct obstruction (CNLDO), Multidetector computed tomography (MDCT), Magnetic resonance imaging (MRI), Dacryocystorhinostomy (DCR), Tear drainage, Pediatric anatomy, Lacrimal system, Anatomical variations, Pediatric radiology.*

1. INTRODUCTION

The nasolacrimal duct (NLD) is an important part of the lacrimal apparatus, which is responsible for draining tears from the eye into the nasal cavity. Here's an overview of its anatomy, side determination, and features:

1.1 Structure and Function

Both the upper eyelid and the lower eyelid have a small opening on the surface of the eyelid margin near the medial canthus. These are called puncta. Each punctum leads to a drainage canal that eventually flows into the lacrimal sac and then the nasal cavity. The drainage canal connecting the ocular surface to the nasal cavity consists of multiple parts.

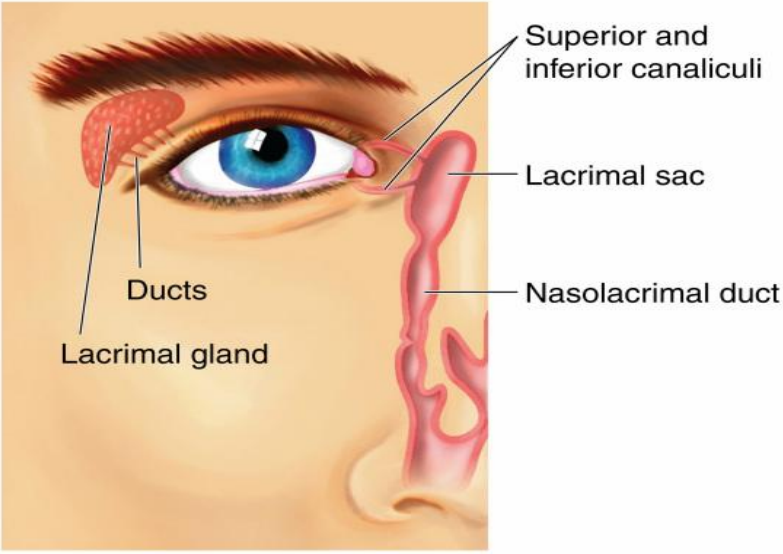


Fig1.1- Nasolacrimal duct

Within the lower eyelid, the punctum leads to a 2 mm long ampulla, which runs perpendicular to the eyelid margin. The ampulla turns 90 degrees medially, becoming the inferior canaliculus and travels 8 to 10 mm before reaching the common canaliculus. The upper canaliculus travels 2 mm superiorly in the eyelid before turning 90 degrees medially and moving 8 to 10 mm before connecting to the common canaliculus. The common canaliculus drains into the lacrimal sac. Within the junction between the common canaliculus and the lacrimal sac is the valve of Rosenmuller. This apparatus is a one-way valve that prevents reflux from the lacrimal sac to the puncta.

The lacrimal sac drains inferiorly to the nasolacrimal duct, which is bordered medially by palatine bone and the inferior turbinate in the nose and laterally by maxillary bone. The nasolacrimal duct opens at the inferior meatus located underneath the inferior nasal turbinate. The lacrimal sac is approximately 10 to 15 mm in axial length and 13 to 20 mm in corneal length, and the nasolacrimal duct is 12 to 18 mm long. The inferior nasal meatus is partially covered by a mucosal fold known as the valve of Hasner.[1][2][3]

1.2 Embryology

The nasolacrimal duct starts forming around five weeks of gestation. It starts out as a linear thickening of ectoderm located in a groove between the nasal and maxillary prominences. This thickening eventually separates into a solid cord and sinks into the surrounding mesenchyme. Over time, the cord canalizes, forming the lacrimal sac and the beginning of the nasolacrimal duct. The nasolacrimal duct extends intranasally until it exits under the inferior turbinate. The lacrimal sac extends caudally to complete the canalicular system. The inside of the canal breaks down and forms a lumen so that the nasolacrimal system is patent. This process is generally complete by the time of birth.[4]

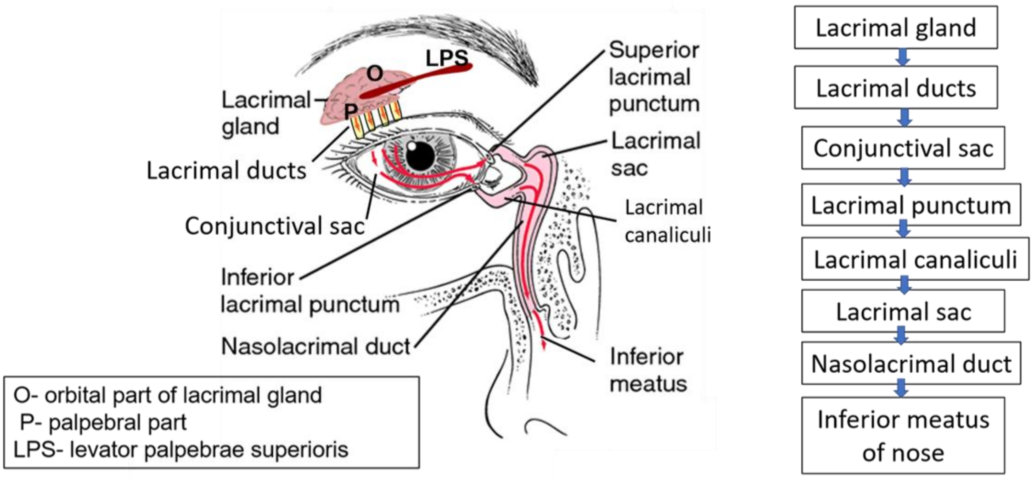


Fig1.2 - lacrimal apparatus

1.3 Blood Supply and Lymphatics

Blood supply to the nasolacrimal area of the face is generally from the angular artery. The angular artery is considered a branch of the facial artery; however, some studies have shown that it can originate from the ophthalmic artery in some individuals. It terminates in anastomosis with the dorsal nasal branch of the ophthalmic artery. The angular artery and vein appear alongside the nose near the medial orbit. A correlating angular vein drains this region.

The medial and lateral portions of the eyelids have different lymphatic drainage systems. The medial one-third of the upper eyelid and the medial two-thirds of the lower eyelid drain to the submandibular lymph nodes. The lateral two-thirds of the upper eyelid and the lateral one-third of the lower eyelid drain to the pre-auricular lymph nodes.

1.4 Nerves

Cranial nerve VII supplies the motor innervation to the muscles of the face. The movement of these muscles aids in proper drainage of the tears through the nasolacrimal system by what is known as the lacrimal pump mechanism. Cranial nerve III and cranial nerve VII innervate the muscles that control the blinking of the eyelids. This action is the primary driver of the lacrimal pump mechanism.

Irritation of the ocular surface stimulates the ophthalmic branch of cranial nerve five, which begins the reflex tear arc pathway. The efferent pathway involves cranial nerve VII and parasympathetic fibres. The role of the sympathetic nervous system in tear production is not well understood.

1.5 Muscles

The action of the orbicularis muscle and surrounding tissues helps propel the flow of tears from the canaliculi to the nasolacrimal duct via the lacrimal pump mechanism.

1.6 CT Scanner –

In 1972, G.N. Hounsfield introduced computed axial transverse scanning, revolutionizing medical imaging. With cross-sectional images of the head, pathologic processes like blood clots, tumours, and strokes could be non-invasively observed. This breakthrough invention eliminated the need for surgery or autopsy and saving countless lives.

1.7 Common Name-

1. Computerized axial transverse scanning (Hounsfield, 1972).

2. Computerized axial tomography (CAT).

3. X-ray computed tomography (X-ray CT).

4. Computed/computerized tomography (CT) Computed tomography (CT) is currently the preferred name.

1.8 History Leading to CT scan-

1. 1917—Radon developed the basic mathematical equations**.**

2. 1940—Frank and Takahashi published the basic principles of axial CT.

3. 1956—Cormack developed the theory of image reconstruction.

4. 1967—Hounsfield developed the clinically useful CT scanner.

5. 1973—First clinical brain scanner in the Mayo Clinic.

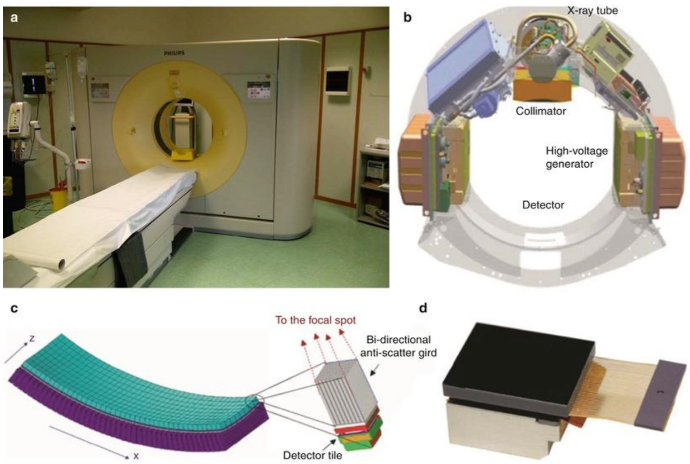


Fig. 1.3 CT Scan Overview

1.9 Working of CT Scanners –

In order to better understand the initial trials and current technologies a technologist must have a good understanding of how a CT scanner works. To ensure the scanner is functioning properly, the technician first turns it on and performs a brief test. The patient is then positioned correctly for the specific scan and placed inside the scanner opening. At the control console, the technologist sets up the technical aspects of the scan. X-rays weaken as 6 they pass through the patient's body and are recorded by detectors. The gantry of the scanner rotates around the patient housing the x-ray tube and detectors. Detectors convert x-ray photons into analog signals then digital data is reconstructed by the computer to provide a clear image of the patient condition. The reconstructed image is transformed into electrical impulses before being viewed on a TV display. The PACS then receives the images and associated data for radiologist analysis. Finally, the image is stored on magnetic tapes or optical disks (3).

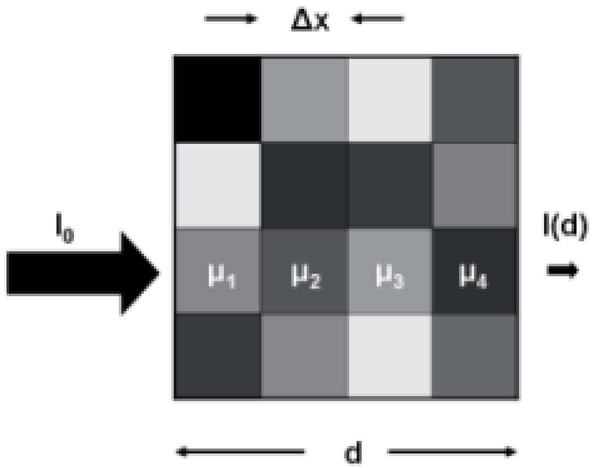


Fig. 1.4- The principle of attenuation of an X ray beam in a simplified 4 × 4 matrix. Each element in the matrix can, in principle, have a different value of the associated linear attenuation coefficient

1.10 Image Reconstruction-

Analog signals are converted into digital signals using an analog-to-digital converter. The digital signal is recorded and then reconstructed to create an image on a matrix of pixels. Each pixel is assigned a number based on the detected energy, known as the Hounsfield unit.

An object's rebuilt anatomy is stored digitally and is made up of several tiny, elongated blocks representing a voxel, or volume of tissue.

A voxel is a 3D tissue element that has width, height, and depth. The depth of a voxel is a vital property determined by the thickness of its slices and is assigned a greyscale color for each unit. A pixel, on the other hand, is a voxel that has been projected onto a computer in two dimensions, and it only has two dimensions: height and breadth

Algorithms For Image Reconstruction-

Using a large number of X-ray transmission measurements, the main difficulty in CT is to calculate the linear attenuation coefficient of the pixels. Then, using an algorithm for computer processing, one may utilize the data to create an image of the item.

A mathematical approach to problem resolution is called an algorithm. To reformat the image, several techniques are applied.

(A) Back projection method.

(B) Iterative method.

(C) Analytical method.

Back–Projection-

The process of back-projection is straightforward and requires little mathematical knowledge. Oldendorf (1961) and Kuhl, Edwards (1963) were the first to employ back-projection, which is also referred to as the summation method or the linear superposition method. A graphical or numerical technique is the most effective way to explain back-projection.

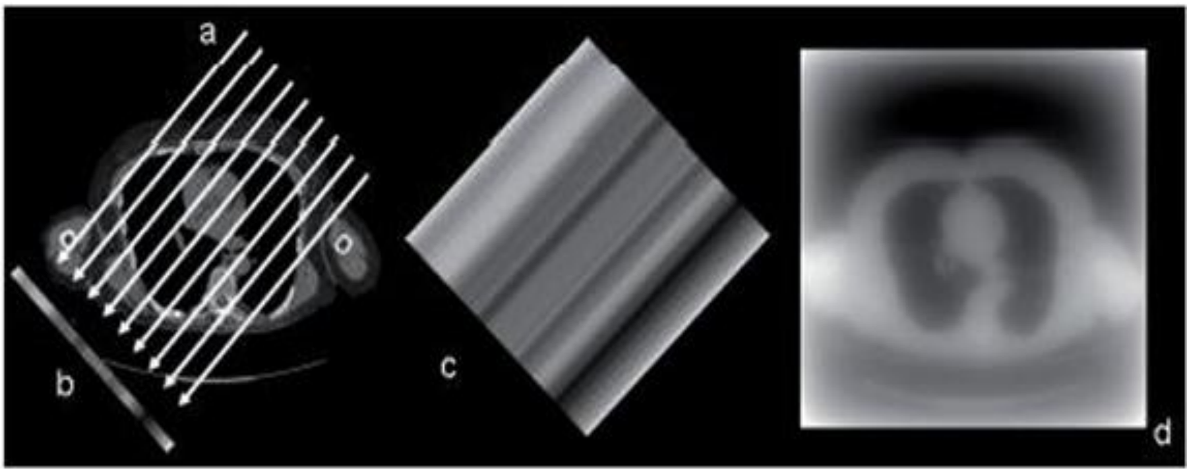


Fig. 1.5. A back projection that is simple produces a markedly hazy image. The picture still shows the features of the lungs and chest.

Iterative Algorithms-

An iterative reconstruction begins with an assumption for example all the points in the matrix have the same value, for example compares the measured values to the assumption, makes adjustments to bring the two into agreement, and then repeats the process until the measured values and the assumed values are equal or fall within acceptable bounds Curry and others (1990). Depending on whether one ray, one point, or the entire matrix is involved in the correction sequence,

There are three different iterative reconstructions.

(A) Simultaneous Reconstruction

(B). Ray-by-Ray Correction

(C) Point-by-Point Correction

Analytical Reconstruction Algorithm-

Modern CT scanners use analytical reconstruction techniques, which were created to get over the drawbacks of back-projection and iterative algorithms.

Two types of analytical reconstruction.

• Fourier reconstruction algorithm

• Filtered back-projection (3).

Table 1.1. Typical HU Values and Ranges of Values for Different Tissues and Materials (25)

Substance	**HU**
Compact bone	+1000 (+300 to +2500)
Liver	+60 (+50 to +70)
Kidneys	+30 (+20 to +40)
Blood	+55 (+50 to +60)
Muscle	+25 (+10 to +40)
Brain, grey matter	+35 (+30 to +40)
Brain, white matter	+25 (+20 to +30)
Water	0
Fat	–90 (–100 to –80)

Lung	–750 (–950 to –600)
Air	–1000

(A)- The temperature and tube voltage and tissue or material composition all affect the actual HU value.

TABLE 1.2-Overview Of Different Types of CT Technology (4)

CT technology	Detector configuration	Axial FOV coverage	Acquisition of axial projection angles	Coverage of longitudinal range
First clinical CT scanners, 1974	Single detector	Pencil beam, with translation of the X ray tube and detector in small discrete steps	Rotation of X ray tube and detector in small discrete angular steps”	Translation of the table in small discrete steps
axial (step and shoot) CT scanners	One single detector row with hundreds of detectors	Fan beam, with full coverage of the FOV	One 360º rotation of the X ray tube and detector	
Helical CT scanners	One single detector row with hundreds of detectors	Fan beam, with full coverage of the FOV	Multiple continuous rotations of the X ray tube and detector	Continuous translation of the table
Helical, MDCT scanners, 1998	Multiple detector rows, e.g. 4–64 active channels	Fan beam, with full coverage of the FOV	Multiple continuous rotations of the X ray tube and detector	Continuous translation of the table
Dual source, helical, MDCT scanner	Two detectors with multiple detector rows, e.g. 32–64 active channels	Two fan beams, with at least one fan beam with full coverage of the FOV	Multiple continuous rotations of two X ray tubes and two detectors	Continuous translation of the table
Volumetric CT scanners, 2007”	Multiple detector rows, currently with up to 320 active channel”	Cone beam, with full volumetric FOV coverage”	One single continuous rotation of the X ray tube and detector”	Coverage (e.g. 160 mm) of the longitudinal range is provided by the cone beam; longitudinal coverage exceeding 160 mm is achieved by step and shoot acquisitions and stitching of the reconstructed volumes

Slip-Ring –

Functions to allow the transfer of electrical information and power between a rotating device and external components. They are used in helical CT and MRI scanners among other applications; in this setting, they allow image acquisition without progressive twisting of cables as the scanner rotates

A rotating circular conductor as opposed to a non-rotating conductive metallic strip to allow a complete circuit to be maintained despite device rotation.

Specific functions of slip rings include:

- transferring high voltage to power the rotating device

- transferring information to the rotating device (for example from a CT control room to the CT scanner)
- transferring information from the rotating device (for example from a CT detector array (24)

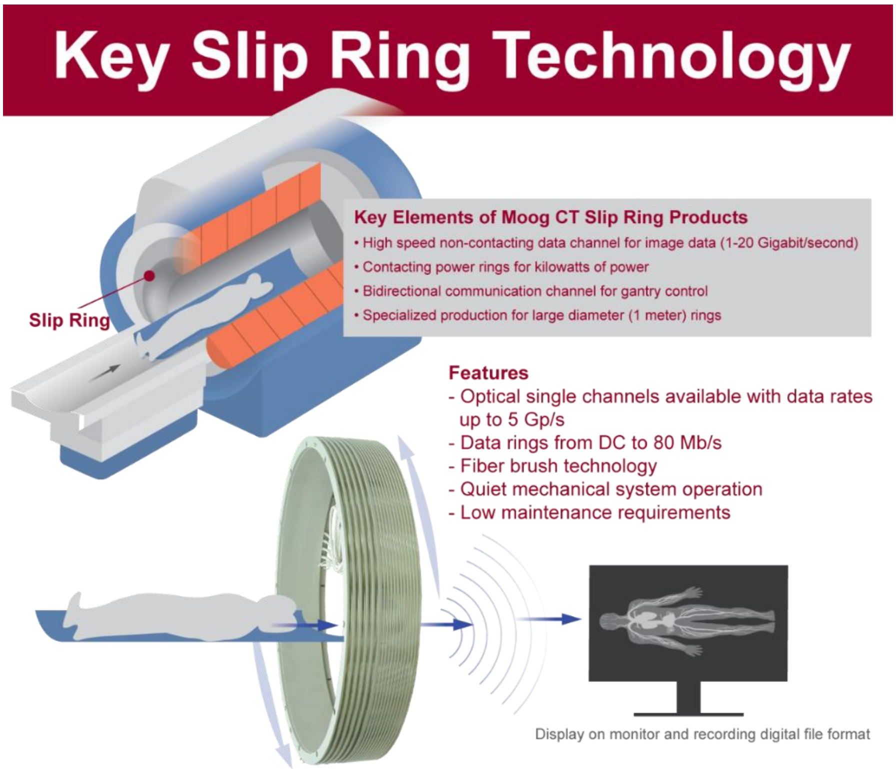


Fig.1.6. slip ring technology

2. AIM AND OBJECTIVES

2.1. AIM-

- Anatomical Parameters of the Nasolacrimal Duct in Children {UP west} Measured with Computed Tomography.
- To evaluate the anatomical parameters of the bony nasolacrimal duct in children using CT scans.
- To assess the feasibility of using CT for this purpose.

3. OBJECTIVE-

- Using anatomical parameters shows differences according to age and gender-related differences in the UP western population
- Measure the width and diameter of the nasolacrimal duct at different levels.
- Analyze the influence of age on these parameters.

3.1 NEED OF THE STUDY –

- The study provides important insights into how the NLD (NASOLACRIMAL DUCT) changes with age in children, which can help guide surgical interventions and instrument selection for pediatric patients with NLD issues.
- The typical anatomy of the NLD can assist in diagnosing and treating congenital and acquired nasolacrimal duct obstructions in children.
- It will help in the measurement of NLD (NASOLACRIMAL DUCT).

4. METHODOLOGY

4.1 Study Site-

Department of Radiology, Teerthanker Mahaveer Hospital and Research Canter, Moradabad, Uttar Pradesh, India.

4.2 Types Of Study –

This was a prospective, observational, clinical-based study and was executed in the Radiology Department at the Teerthanker Mahaveer Hospital and Research Canter, Moradabad, Uttar Pradesh, India.

4.3 Study Design-

This study was designed as a cross-sectional-based consideration, to identify Morphometric variation in the Nasolacrimal duct according to Age.

4.4 Study Population-

In this study, we are selecting the western up population that came for the PNS CT scan examination in Teerthanker Mahaveer Hospital and Research Canter Moradabad, India.

4.5 Study Duration-

1 year for this prospective study managed at Teerthanker Mahaveer Hospital and research center in Moradabad. Uttar Pradesh India.

4.6 Study Criteria –

- **Inclusion Criteria-**

- Male and female patients between 1 month and 20 years of age, from the database of the Radiology and Imaging Department at the University Hospital, who underwent a PNS CT scan examination.
- No facial features.
- Included patient age between 1month to 20 years
- Patient included with no pathology of Nasolacrimal Duct and nose.

- **Exclusion Criteria-**

- Those patients with facial Trauma.
- Children with facial birth defects or previous surgeries in the face or nose.
- CT scans with blurry images.
- Exclude patients whose age above 20 years
- Sinusitis
- Traumatic patients are excluded

4.7 Sample Size-

One hundred sixty-eight patients will participate in this trial.

4.8 Materials-

4.8.1 PNS CT Protocols-

The CT paranasal sinus protocol serves as an examination for the assessment of the study of the mucosa and bone system of the sinonasal cavities. It is usually performed as a non-contrast study.

Table 4.1 PNS CT Protocols

Ct scanner	Philips Ingenuity 128 CT Scanner helical tomography
Collimation	64×0.625
FOV	220
Matrix	512
Slice thickness	1 mm
Increment	0.5 mm
Kvp	120
MAs	200

4.9 Methods-

The anatomical parameter of the nasolacrimal duct is measured using multiplanar reformat. The Diameter of the nasolacrimal duct is measured on the Axial plane (anterior, posterior diameter at the inferior orbital margin line, and the narrowest diameter of NLD) by using Radiant DICOM viewer v.2023.1

4.10 Statistical Analysis-

The collected data were summarized by using the Descriptive Statistics: frequency, percentage, mean, and S.D. The Independent sample "t" test was used to compare age, anterior-posterior diameter, transverse diameter, and narrowest diameter between males and females. The One-way ANOVA was used to compare age, anterior-posterior diameter, transverse diameter, and narrowest diameter between the groups. The Post hoc analysis, Tukey test was used for the multiple comparisons. To find the relation between anterior-posterior diameter, transverse diameter, narrowest diameter, and age; the Pearson correlation coefficient: ("r") was used. The p value < 0.05 was considered as significant. Data were analyzed by using the SPSS software (SPSS Inc.; Chicago, IL) version 29.0.10.

5. RESULTS

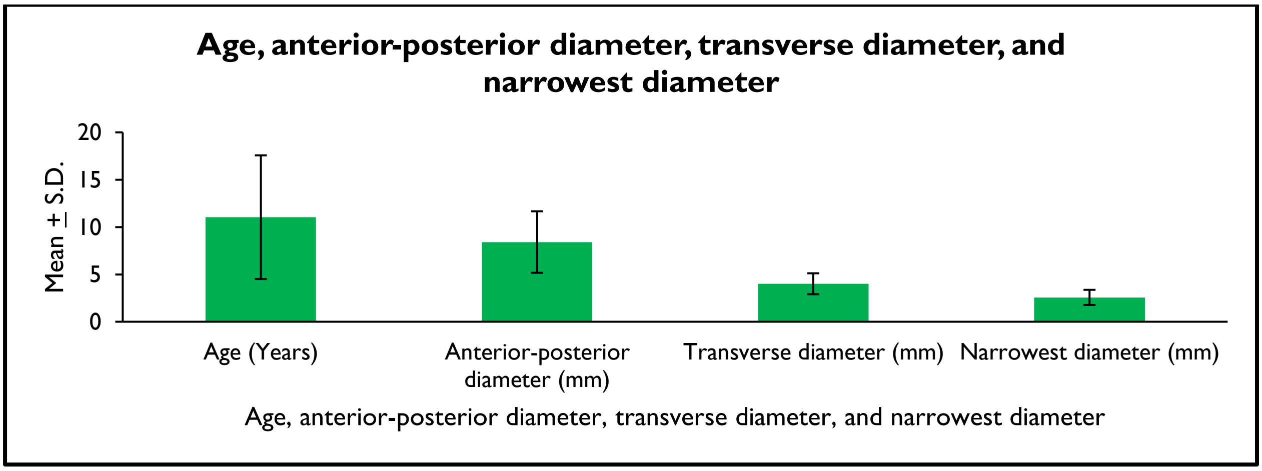
5.1 OBSERVATION

We conducted a prospective cross-sectional study on a total of 168 patients in which 88 male patients and 80 female individuals were directed to for PNS computed tomography to the Department of Radio-Diagnosis and Imaging at Teerthanker Mahaveer Hospital under the aegis of the College of Paramedical Sciences, Teerthanker Mahaveer University Research Canter Moradabad.

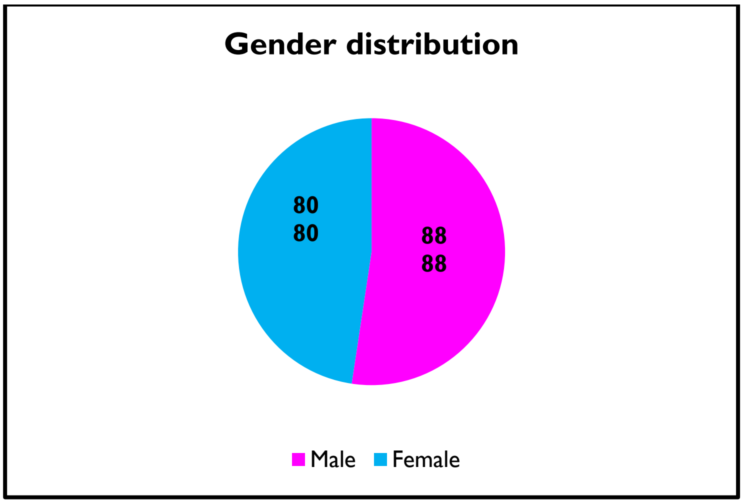
Table 5.1.: Descriptive Statistics for age, anterior-posterior diameter, transverse diameter, and narrowest diameter

(n = 168)	Range	Mean	S.D.
Age (Years)	1 to 20	11.04	6.53
Anterior-posterior diameter (mm)	1.24 to 15.73	8.42	3.25
Transverse diameter (mm)	1.92 to 6.93	4.01	1.11
Narrowest diameter (mm)	1.12 to 4.87	2.57	0.80

Age of the participants ranged from 1 to 20 years with mean: 11.04 $\pm$ 6.53 years; anterior-posterior diameter ranged from 1.24 to 15.73 mm with mean: 8.42 $\pm$ 3.25 mm; transverse diameter ranged from 1.92 to 6.93 mm with mean: 4.01 $\pm$ 1.11 mm; and the narrowest diameter ranged from 1.12 to 4.87 mm with mean: 2.57 $\pm$ 0.80 mm. [Table – 1]



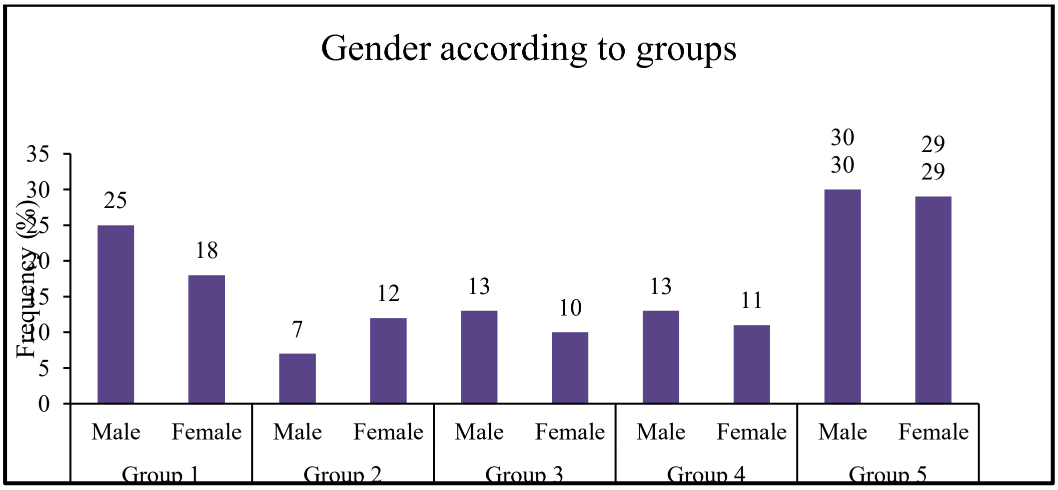
Graph 5.1- Bar graph representation of Age, anterior-posterior diameter, transverse diameter, and narrowest diameter



Graph 5.2- Gender distribution

Table 5.2.: Distribution of gender and groups

		Frequency	%
Gender	Male	88	52.4
	Female	80	47.6
Groups	Group 1	43	25.6
	Group 2	19	11.3
	Group 3	23	13.7
	Group 4	24	14.3
	Group 5	59	35.1



Graph 5.3- Gender according to groups

Table 5.3.: Comparison of gender between the groups

Groups	Gender				Chi square	p value
	Male		Female			
	n	%	n	%		
Group 1	25	28.4	18	22.5	2.66	0.617
Group 2	7	8.0	12	15.0		
Group 3	13	14.8	10	12.5		
Group 4	13	14.8	11	13.8		
Group 5	30	34.1	29	36.3		

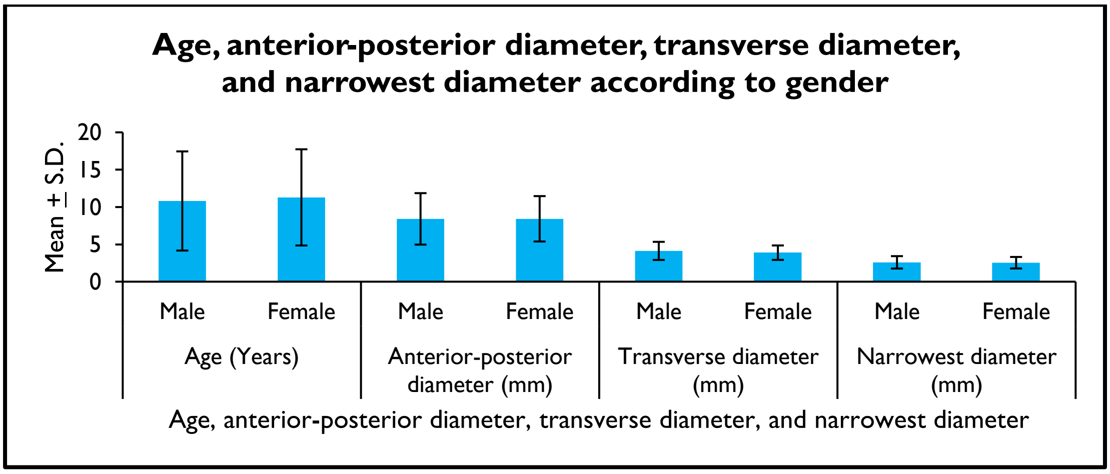
The Chi square test was used to compare gender; between the groups. There was no difference (p > 0.05) in the gender; between the groups. [Table – 3]

Table 5.4.: Comparison of age, anterior-posterior diameter, transverse diameter, and narrowest diameter according to gender

		Mean	S.D.	"t"	p value
Age (Years)	Male	10.81	6.64	-0.48	0.635
	Female	11.29	6.44		
Anterior-posterior diameter (mm)	Male	8.41	3.45	-0.02	0.985
	Female	8.42	3.04		
Transverse diameter (mm)	Male	4.13	1.21	1.40	0.164
	Female	3.89	0.97		
Narrowest diameter (mm)	Male	2.59	0.83	0.40	0.691
	Female	2.54	0.77		

("t" = Independent sample "t" test)

The Independent sample "t" test was used to compare age, anterior-posterior diameter, transverse diameter, and narrowest diameter; according to gender. There was no difference (p > 0.05) in the age, anterior-posterior diameter, transverse diameter, as well as narrowest diameter; between males and females. [Table – 4]



Graph 5.4- Age, anterior-posterior diameter, transverse diameter, and narrowest diameter according to gender

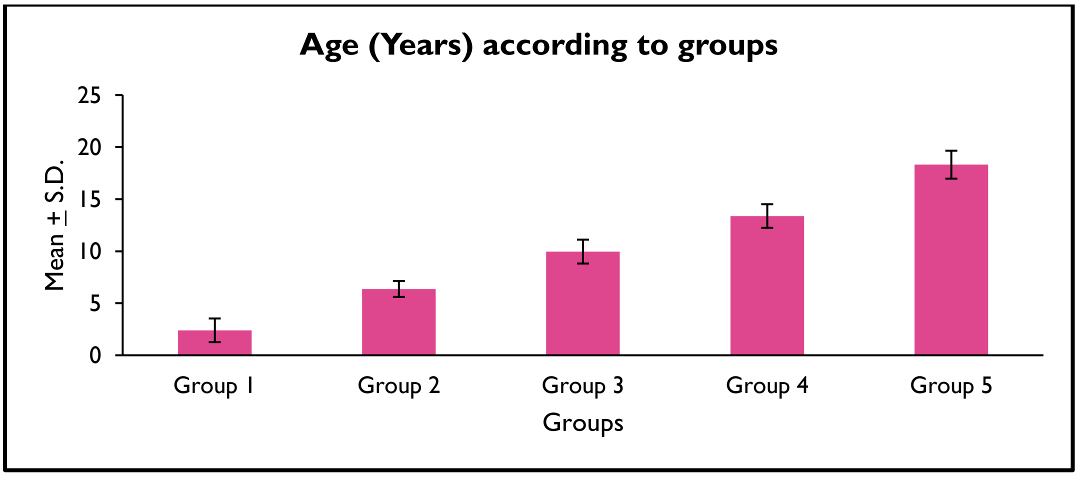
Table 5.5.: Comparison of age, anterior-posterior diameter, transverse diameter, and narrowest diameter between the groups

		Mean	S.D.	"F"	p value
Age (Years)	Group 1	2.40	1.14	1234.36	< 0.001*
	Group 2	6.37	0.76		
	Group 3	9.96	1.15		
	Group 4	13.38	1.14		
	Group 5	18.31	1.34		
Anterior-posterior diameter (mm)	Group 1	4.86	1.83	68.91	< 0.001*
	Group 2	7.08	1.00		
	Group 3	7.94	1.28		
	Group 4	9.04	2.67		
	Group 5	11.37	2.26		
Transverse diameter (mm)	Group 1	3.05	0.87	33.67	< 0.001*
	Group 2	3.41	0.38		
	Group 3	3.86	0.54		
	Group 4	4.22	1.10		
	Group 5	4.88	0.86		
Narrowest diameter (mm)	Group 1	1.82	0.38	66.97	< 0.001*
	Group 2	2.06	0.34		
	Group 3	2.42	0.43		
	Group 4	2.51	0.59		
	Group 5	3.36	0.59		

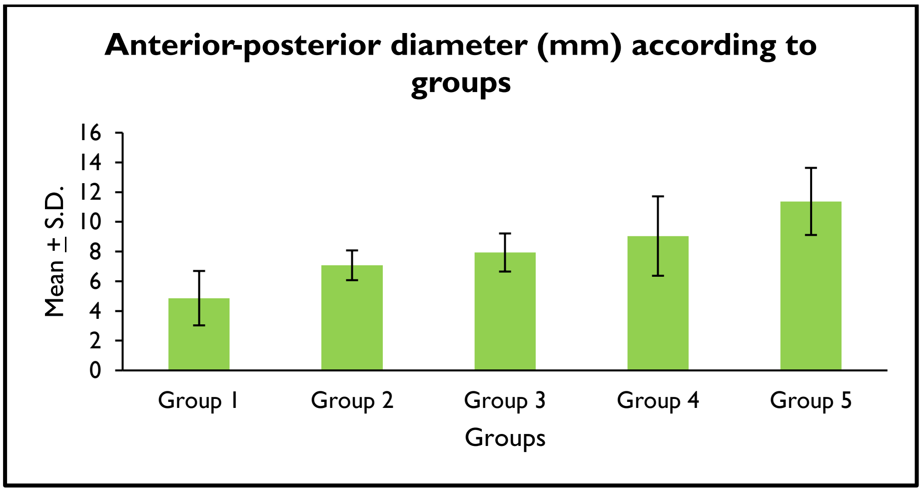
("F" = One-way ANOVA; * Significant)

The One-way ANOVA was used to compare age, anterior-posterior diameter, transverse diameter, and narrowest diameter; between the groups. There was a difference ($p < 0.05$) in the age, anterior-posterior diameter, transverse diameter, as well as narrowest diameter between the groups. [Table – 5]

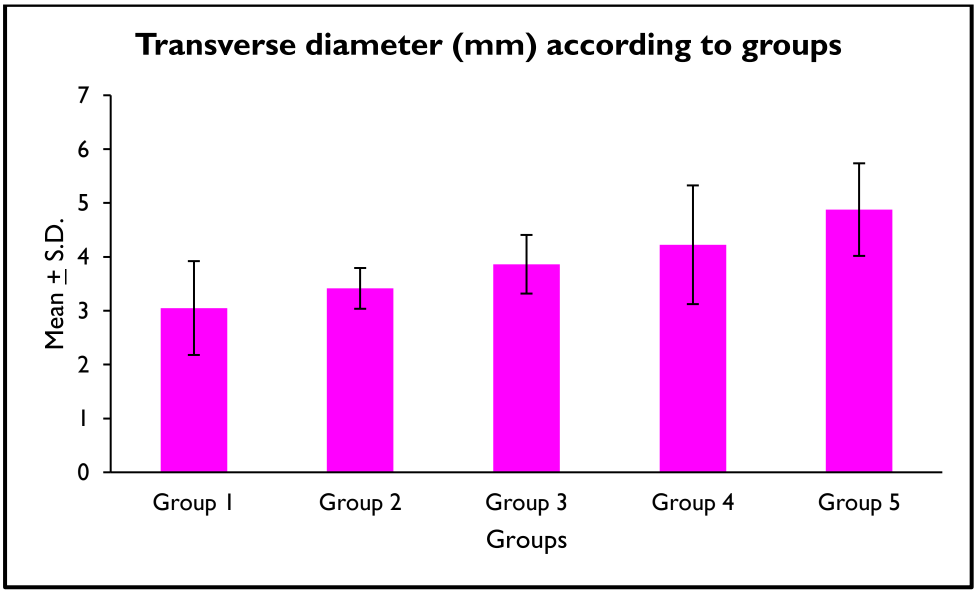
Graph 5.5- Age (Years) according to groups



Graph 5.6- Anterior-Posterior diameter (mm) according to groups



Graph 5.7- Transverse diameter (mm) according to groups



Graph 5.8- Narrowest diameter (mm) according to groups

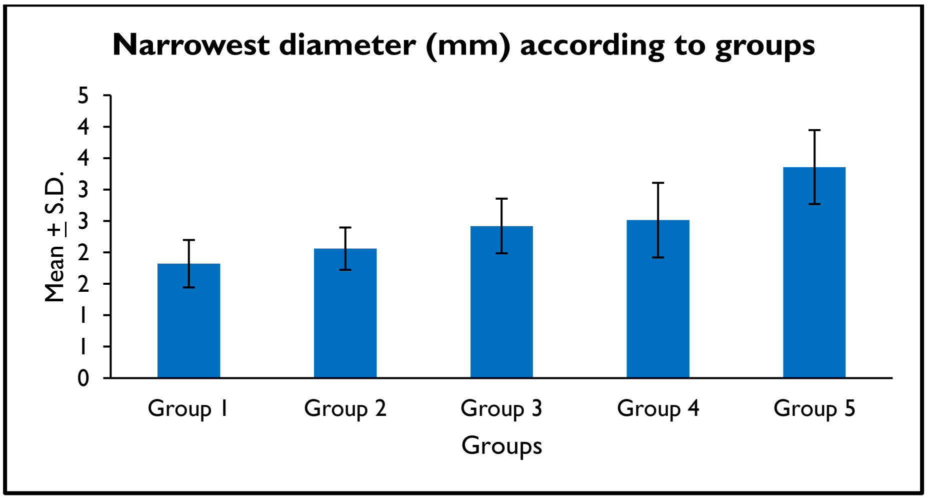


Table 5.6. Multiple comparisons of age, anterior-posterior diameter, transverse diameter, and narrowest diameter between the groups

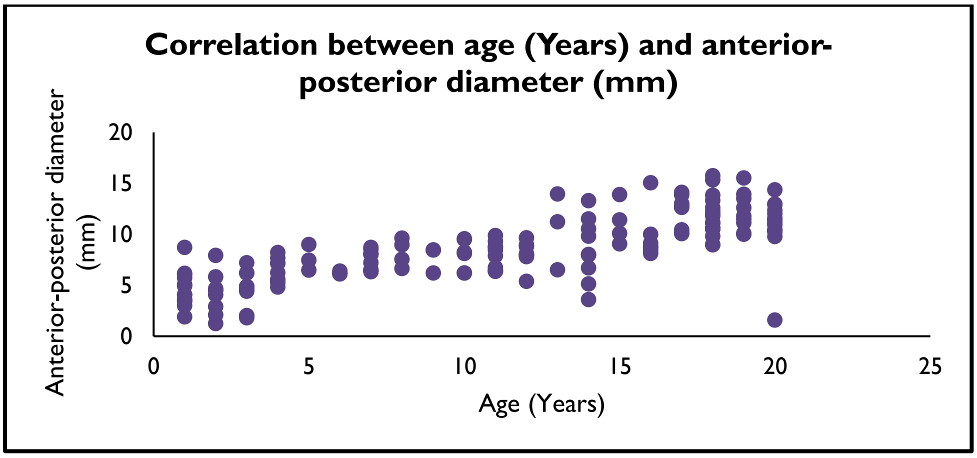
Multiple comparisons		Mean Difference	p value
Age (Years)	Group 1 vs. Group 2	-3.97	< 0.001*
	Group 1 vs. Group 3	-7.56	< 0.001*
	Group 1 vs. Group 4	-10.98	< 0.001*
	Group 1 vs. Group 5	-15.91	< 0.001*
	Group 2 vs. Group 3	-3.59	< 0.001*
	Group 2 vs. Group 4	-7.01	< 0.001*
	Group 2 vs. Group 5	-11.94	< 0.001*
	Group 3 vs. Group 4	-3.42	< 0.001*
	Group 3 vs. Group 5	-8.35	< 0.001*
	Group 4 vs. Group 5	-4.93	< 0.001*
Anterior-posterior diameter (mm)	Group 1 vs. Group 2	-2.21	0.001*
	Group 1 vs. Group 3	-3.07	< 0.001*
	Group 1 vs. Group 4	-4.18	< 0.001*
	Group 1 vs. Group 5	-6.51	< 0.001*
	Group 2 vs. Group 3	-0.86	0.639
	Group 2 vs. Group 4	-1.97	0.014*
	Group 2 vs. Group 5	-4.30	< 0.001*
	Group 3 vs. Group 4	-1.11	0.325
	Group 3 vs. Group 5	-3.44	< 0.001*
	Group 4 vs. Group 5	-2.33	< 0.001*
Transverse diameter (mm)	Group 1 vs. Group 2	-0.36	0.500
	Group 1 vs. Group 3	-0.81	0.002*
	Group 1 vs. Group 4	-1.17	< 0.001*
	Group 1 vs. Group 5	-1.83	< 0.001*
	Group 2 vs. Group 3	-0.45	0.410
	Group 2 vs. Group 4	-0.81	0.015*
	Group 2 vs. Group 5	-1.46	< 0.001*
	Group 3 vs. Group 4	-0.36	0.565
	Group 3 vs. Group 5	-1.01	< 0.001*
	Group 4 vs. Group 5	-0.65	0.012*
Narrowest diameter (mm)	Group 1 vs. Group 2	-0.24	0.405
	Group 1 vs. Group 3	-0.60	< 0.001*
	Group 1 vs. Group 4	-0.69	< 0.001*

	Group 1 vs. Group 5	-1.54	< 0.001*
	Group 2 vs. Group 3	-0.36	0.140
	Group 2 vs. Group 4	-0.45	0.028*
	Group 2 vs. Group 5	-1.30	< 0.001*
	Group 3 vs. Group 4	-0.09	0.968
	Group 3 vs. Group 5	-0.94	< 0.001*
	Group 4 vs. Group 5	-0.84	< 0.001*

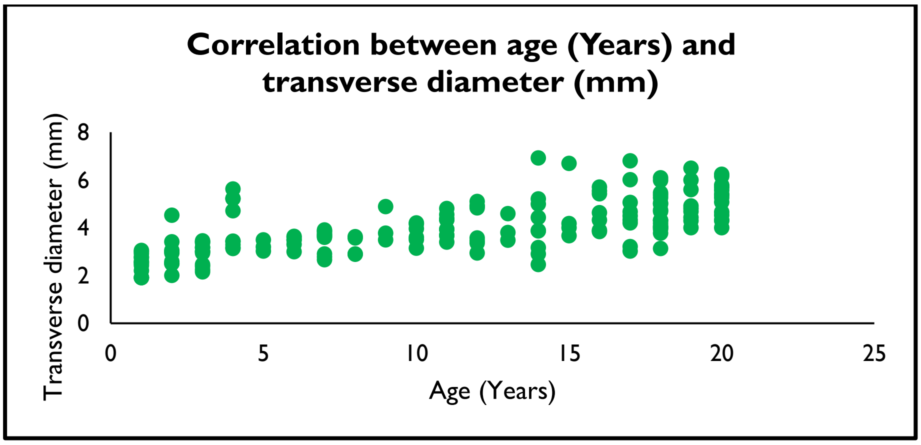
(* Significant)

The Post hoc analysis, Tukey test was used for the multiple comparisons of age, anterior-posterior diameter, transverse diameter, and narrowest diameter between the groups. There was a difference ($p < 0.05$) in the age between: Group 1 vs. group 2, group 1 vs. group 3, group 1 vs. group 4, group 1 vs. group 5, group 2 vs. group 3, group 2 vs. group 4, group 2 vs. group 5, group 3 vs. group 4, group 3 vs. group 5, and group 4 vs. group 5. The anterior-posterior diameter (mm) was found to be different ($p < 0.05$) between: Group 1 vs. group 2, group 1 vs. group 3, group 1 vs. group 4, group 1 vs. group 5, group 2 vs. group 4, group 2 vs. group 5, group 3 vs. group 5, and group 4 vs. group 5. The transverse diameter (mm) exhibited a difference ($p < 0.05$) between: Group 1 vs. group 3, group 1 vs. group 4, group 1 vs. group 5, group 2 vs. group 4, group 2 vs. group 5, group 3 vs. group 5, and group 4 vs. group 5. Also, there was a difference ($p < 0.05$) in the narrowest diameter between: Group 1 vs. group 3, group 1 vs. group 4, group 1 vs. group 5, group 2 vs. group 4, group 2 vs. group 5, group 3 vs. group 5, and group 4 vs. group 5. [Table – 6]

Graph 5.9- correlation between age (Year) and anterior-posterior diameter (mm)



Graph 5.10- correlation between age (Year) and transverse diameter (mm)



Graph 5.11- correlation between age (Year) and narrowest diameter (mm)

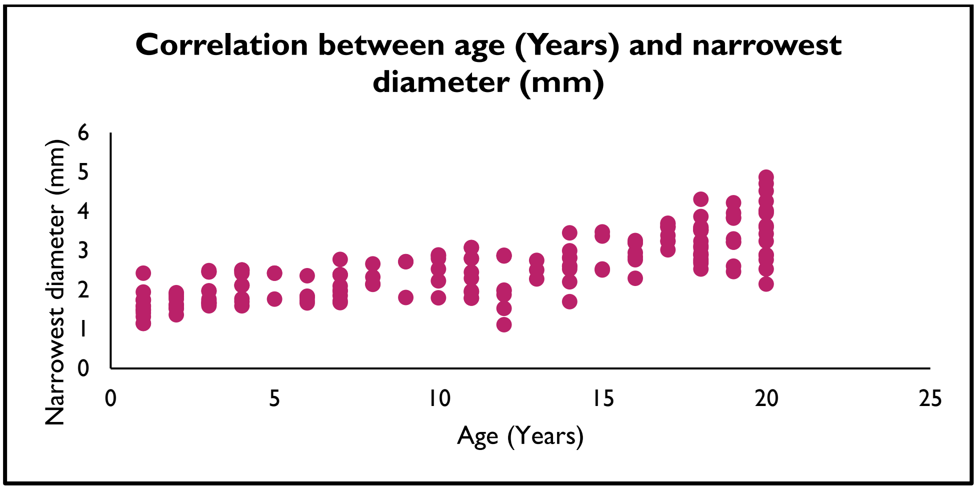


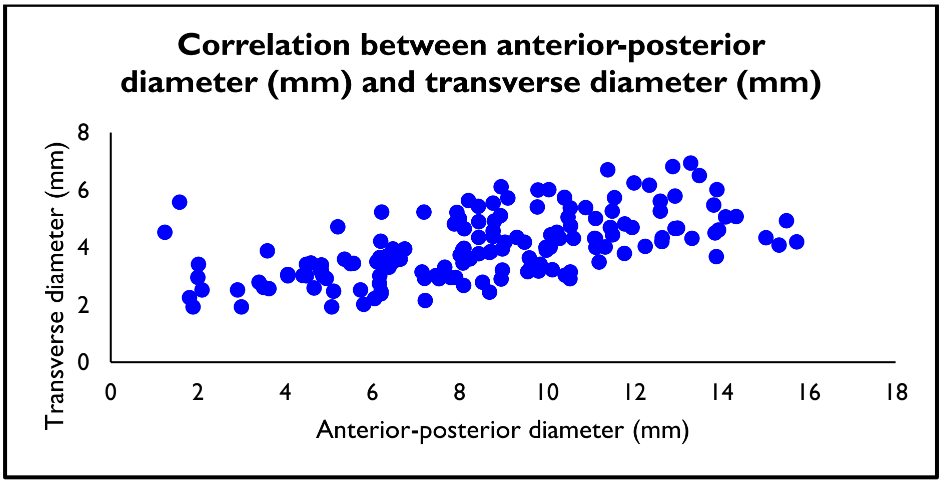
Table 5.7.: Relation between anterior-posterior diameter, transverse diameter, and narrowest diameter

		Anterior-posterior diameter (mm)	Transverse diameter (mm)	Narrowest diameter (mm)
Anterior-posterior diameter (mm)	"r"	1	0.590	0.703
	p value	--	< 0.001*	< 0.001*
Transverse diameter (mm)	"r"		1	0.639
	p value		--	< 0.001*
Narrowest diameter (mm)	"r"			1
	p value			--

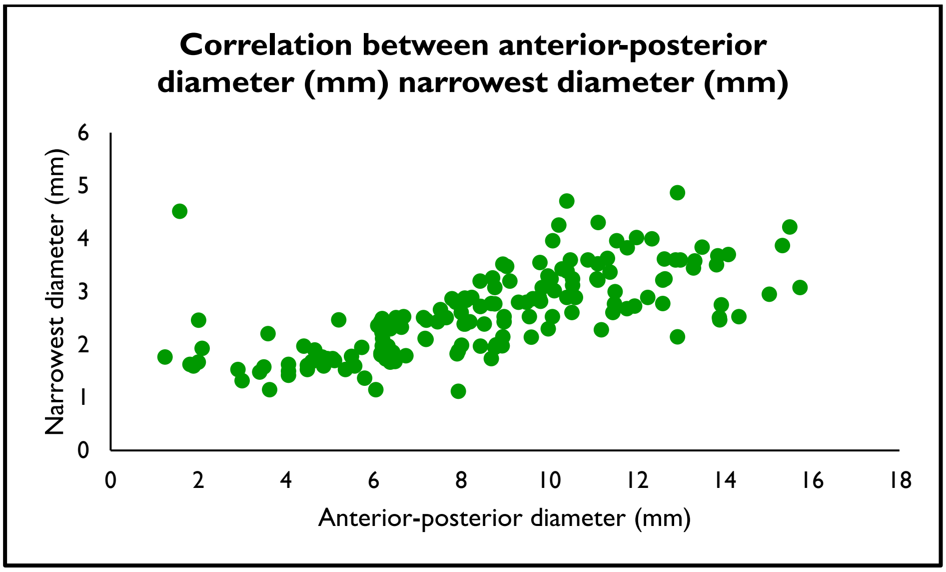
(“r” = Pearson correlation coefficient; * Significant)

The Pearson correlation coefficient: (“r”) was used to find the relation between anterior-posterior diameter, transverse diameter, and narrowest diameter. The anterior-posterior diameter (mm) was positively correlated ($p < 0.05$) with transverse diameter (mm), as well as narrowest diameter (mm). Also, there was a positive correlation ($p < 0.05$) between transverse diameter (mm) and narrowest diameter (mm). [Table – 7]

Graph 5.12- correlation between anterior-posterior diameter (mm) and transverse diameter (mm)



Graph 5.13- correlation between anterior-posterior diameter (mm) and narrowest diameter (mm)



Graph 5.14- correlation between transverse diameter (mm) and narrowest diameter (mm)

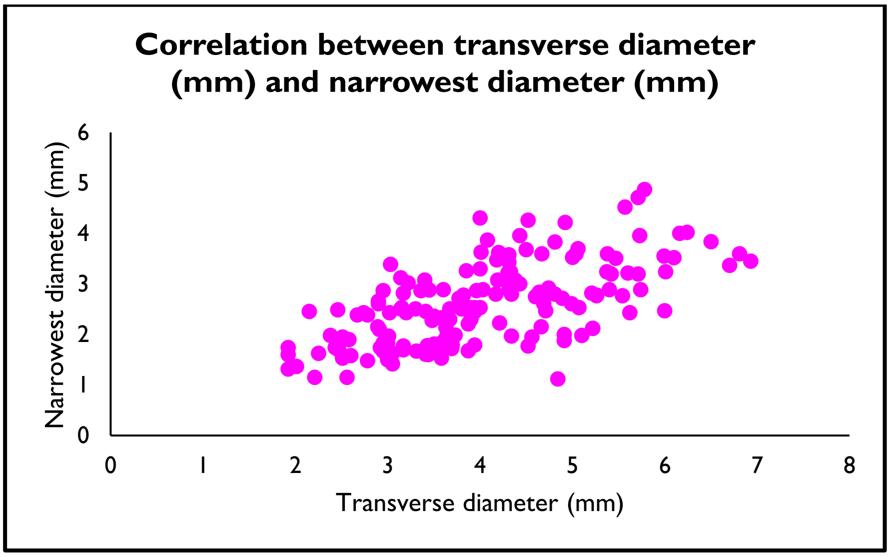


Table 5.8.: Relation between anterior-posterior diameter, transverse diameter, and narrowest diameter according to groups

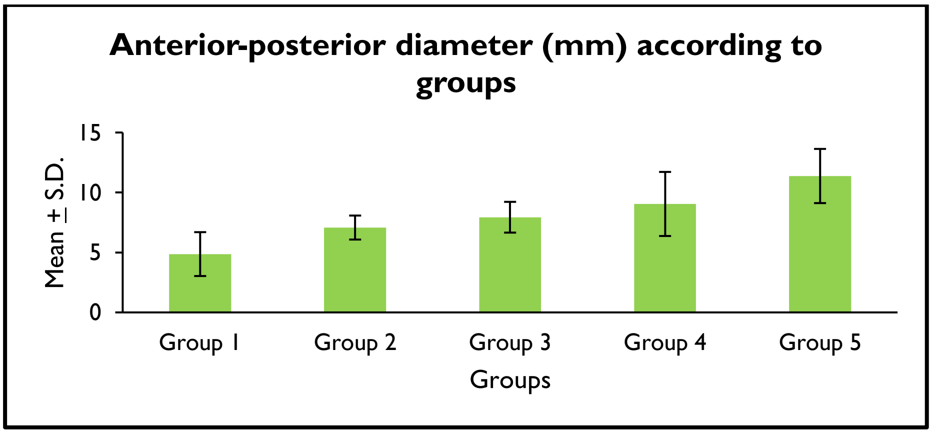
			Anterior-posterior diameter (mm)	Transverse diameter (mm)	Narrowest diameter (mm)
Group 1	Anterior-posterior diameter (mm)	"r"	1	0.222	0.428
		p value	--	0.152	0.004*
	Transverse diameter (mm)	"r"		1	0.396
		p value		--	0.009*
	Narrowest diameter (mm)	"r"			1
		p value			--
Group 2	Anterior-posterior	"r"	1	-0.252	0.790

	diameter (mm)	p value	--	0.298	< 0.001*
	Transverse diameter (mm)	"r"		1	-0.251
		p value		--	0.299
	Narrowest diameter (mm)	"r"			1
		p value			--
Group 3	Anterior-posterior diameter (mm)	"r"	1	0.070	0.541
		p value	--	0.751	0.008*
	Transverse diameter (mm)	"r"		1	0.163
		p value		--	0.457
	Narrowest diameter (mm)	"r"			1
		p value			--
Group 4	Anterior-posterior diameter (mm)	"r"	1	0.350	0.496
		p value	--	0.093	0.014*
	Transverse diameter (mm)	"r"		1	0.260
		p value		--	0.221
	Narrowest diameter (mm)	"r"			1
		p value			--
Group 5	Anterior-posterior diameter (mm)	"r"	1	-0.018	-0.036
		p value	--	0.893	0.786
	Transverse diameter (mm)	"r"		1	0.253
		p value		--	0.054
	Narrowest diameter (mm)	"r"			1
		p value			--

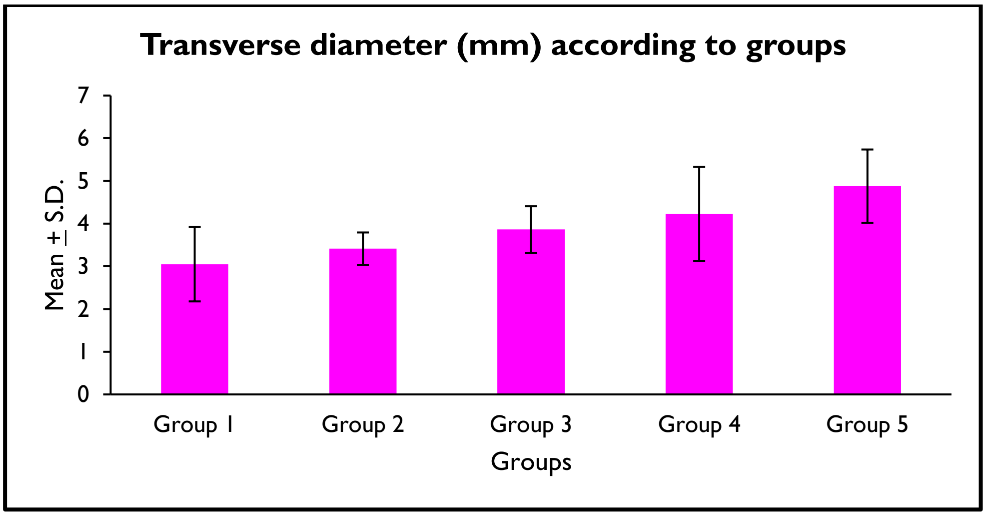
(“r” = Pearson correlation coefficient; * Significant)

The Pearson correlation coefficient: (“r”) was used to find the relation between anterior-posterior diameter, transverse diameter, and narrowest diameter; according to groups. Among group 1, the narrowest diameter was positively correlated with anterior-posterior diameter (mm) as well as transverse diameter (mm). Also, a positive correlation ($p < 0.05$) was found between anterior-posterior diameter (mm) and narrowest diameter (mm); within group 2, group 3, and group 4. [Table – 8]

Graph 5.15- anterior-posterior diameter (mm) according to groups



Graph 5.16- transverse diameter (mm) according to groups



Graph 5.17- Narrowest diameter (mm) according to groups

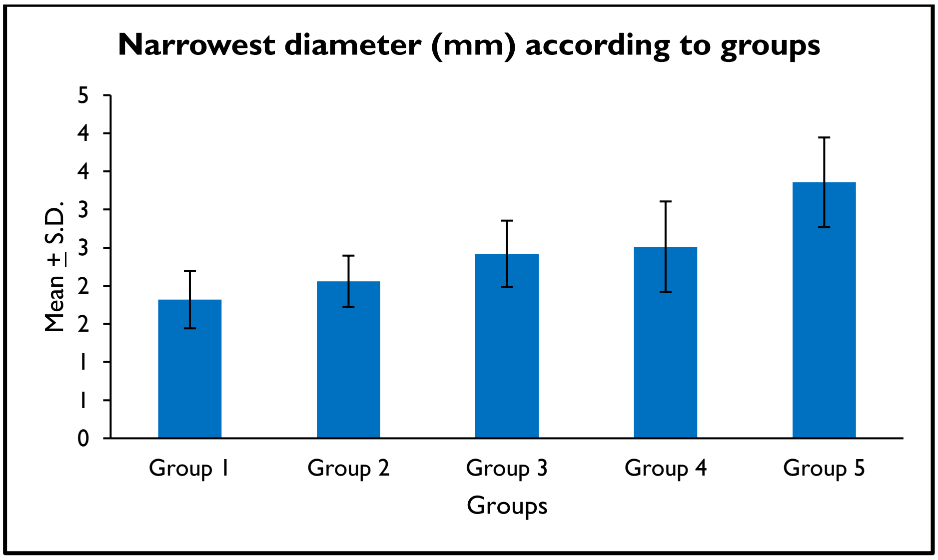


Table 5.9.: Relation of anterior-posterior diameter, transverse diameter, and narrowest diameter with age

	Age (Years)	
	"r"	p value
Anterior-posterior diameter (mm)	0.792	< 0.001*
Transverse diameter (mm)	0.705	< 0.001*
Narrowest diameter (mm)	0.796	< 0.001*

("r" = Pearson correlation coefficient; * Significant)

The Pearson correlation coefficient: ("r") was used to find the relation of anterior-posterior diameter, transverse diameter, and narrowest diameter with age. The anterior-posterior diameter (mm), transverse diameter (mm), as well as narrowest diameter (mm) were positively correlated ($p < 0.05$) with age. [Table – 9]

Table 5.10.: Relation of anterior-posterior diameter, transverse diameter, and narrowest diameter with age according to groups

		Age (Years)	
		"r"	p value
sGroup 1	Anterior-posterior diameter (mm)	0.296	0.054
	Transverse diameter (mm)	0.598	< 0.001*
	Narrowest diameter (mm)	0.547	< 0.001*
Group 2	Anterior-posterior diameter (mm)	0.131	0.592
	Transverse diameter (mm)	0.194	0.426
	Narrowest diameter (mm)	0.048	0.846
Group 3	Anterior-posterior diameter (mm)	-0.050	0.820
	Transverse diameter (mm)	0.493	0.017*
	Narrowest diameter (mm)	0.056	0.798
Group 4	Anterior-posterior diameter (mm)	0.279	0.188
	Transverse diameter (mm)	0.133	0.534
	Narrowest diameter (mm)	0.502	0.012*
Group 5	Anterior-posterior diameter (mm)	0.037	0.782
	Transverse diameter (mm)	0.247	0.059
	Narrowest diameter (mm)	0.285	0.029*

("r" = Pearson correlation coefficient; * Significant)

The Pearson correlation coefficient: ("r") was used to find the relation of anterior-posterior diameter, transverse diameter, and narrowest diameter with age; according to groups. Among group 1; the transverse diameter (mm), as well as narrowest diameter (mm) were positively correlated ($p < 0.05$) with age (Years). There was a positive correlation ($p < 0.05$) between transverse diameter (mm) and age (Years); among group 3. Also, the narrowest diameter (mm) was positively correlated ($p < 0.05$) with age; among group 4, as well as group 5. [Table – 10]

6. DISCUSSION

The current study (n = 168; age 1–20 years) provides a detailed morphometric analysis of the nasolacrimal duct (NLD) using CT imaging, focusing on age and gender-based changes in duct dimensions (anterior-posterior, transverse, and narrowest diameters). It reveals statistically significant increases in all diameters with age ($p < 0.001$) and strong interdimensional correlations, suggesting coordinated ductal growth throughout childhood and adolescence.

6.1 Comparison with Altinkaynak Study:

Altinkaynak's study (n = 289; age 0–15 years) corroborates the age-related increase in NLD size but lacks the granularity of age stratification. It uniquely assesses duct **length and orientation angle**, showing length increases with age, while angle remains stable, important for surgical planning. Unlike the current study, it found **no significant change in the narrowest diameter** post age 3 (p = 0.25). (25)

6.2 Comparison with Sathiamoorthi / Olmsted County Study:

The Olmsted County epidemiological study (17,713 newborns) focuses on **CNLDO prevalence** (1 in 9 births) and demographic associations, including higher incidence in **Caucasians and premature infants**. While not assessing anatomical development, it aligns with the current study in finding **no gender differences**. It contributes insights on **clinical presentation timing** and symptomatology, unlike the anatomical emphasis of the current study. (6)

6.3 Comparison with Czyz Study:

Czyz's study explored **aeration and anatomical variation** across age groups and genders. It observed **reduced aeration**

with aging, potentially linked to PANDO, contrasting with the current study's focus on pediatric dimensional growth. Both studies found **no significant gender differences** in NLD size. Czyz's findings highlight **adult degeneration**, while the current study emphasizes **pediatric maturation**. (7)

Table 6.1 Comparative Table: Current Study vs Other Studies

Aspect	Current Study	Altinkaynak Study	Sathiamoorthi/Olmsted (Epidemiological)	Czyz Study
Sample Size	168	289	17,713	Not specified
Age Range	1–20 years	0–15 years	Newborns	Broad adult age groups
Age Grouping	5 narrow age groups	Broad (above/below 5 years)	Not applicable	Broad adult groupings
Main Focus	Morphometric growth, age/gender comparison	Duct dimensions, length, orientation angle	Prevalence, demographics, diagnosis age	Aeration, anatomical aging, gender differences
Dimensional Parameters	AP, transverse, narrowest diameters	Same + duct length and angle	Not assessed	Diameter, area, aeration
Age-Related Findings	All diameters ↑ with age ($p < 0.001$)	↑ in dimensions post-5 yrs; narrowest NS	Median diagnosis: 5 weeks	↓ aeration with age; adult degeneration focus
Statistical Analysis	ANOVA, post hoc, Pearson correlations	Basic age group comparison	Descriptive statistics	Age-gender comparison, aeration scoring
Gender Differences	None observed ($p > 0.05$)	Not assessed	None observed	No size differences; aeration more complete in males
Unique Contributions	Group-based correlation analysis, clinical planning	Duct orientation angle; surgical planning	Large-scale prevalence; racial/prematurity data	Aeration & risk for adult obstruction (PANDO)
Clinical Relevance	Age-specific surgical planning for DCR, probing	Surgical instrument planning	Early screening, population risk factors	Adult PANDO risk, relevance of aeration changes

Table 6.2 Comparative Table: Current Study vs Other Studies

Feature	Current Study	Altinkaynak	Sathiamoorthi / Olmsted	Craig N. Czyz
Sample Size	168	289	17,713 newborns	Adults (exact n not specified)
Age Range	1–20 years	0–15 years	Newborns	Adults (mainly >30 yrs)
Age Grouping	5 detailed groups	2 broad groups	Not grouped	Broad adult ranges

		(</> 5 years)	anatomically	
Main Focus	NLD dimensions (CT); age & gender effects	NLD dimensions (CT); age	CNLDO prevalence; demographics	NLD aeration decline with age
Key Findings on Age	All diameters increase significantly ($p < 0.001$)	Growth noted post age 5	Diagnosis typically at 5 weeks	Aeration decreases with age
Key Findings on Age	All diameters increase significantly ($p < 0.001$)	Growth noted post age 5	Diagnosis typically at 5 weeks	Aeration decreases with age
Narrowest Diameter	Significant increase ($p < 0.001$)	Non-significant ($p = 0.25$)	Not measured	Not measured
Gender Differences	None ($p > 0.05$)	Not analyzed	None reported	None in diameter; aeration better in males
Correlations Between Dimensions	Strong inter-parameter correlations ($r = 0.59$–0.703)	Not assessed	Not assessed	Not assessed
Anatomical Features Studied	Anterior-posterior, transverse, narrowest diameters	Same	Demographics, diagnosis age	Aeration, anatomical variation
Length/Angle	Not evaluated	Length ↑ with age; angle stable	Not applicable	Not evaluated
Clinical/Surgical Relevance	High: Guides paediatric DCR & probing	Moderate: Basic growth data	High: Prevalence & diagnosis timing	High: PANDO risk factors in adults

7. CONCLUSION

This study offers valuable normative data on the anatomical development of the NLD in children, showing clear age-related increases in duct diameter and length. These parameters, which are positively correlated with one another and with age, can serve as a reference for clinicians in diagnostic imaging and surgical planning for pediatric NLD disorders.

The current study provides a comprehensive, dimension-specific analysis of the nasolacrimal duct in children and adolescents, establishing age-related normative data critical for clinical diagnosis and surgical planning. When compared to prior studies:

- **Altinkaynak** supports general growth trends but lacks granular analysis.
- **Sathiamoorthi/Olmsted County** provides a broad epidemiological context but no anatomical data.
- **Craig N. Czyz** shifts focus to functional decline in adulthood, highlighting contrasting mechanisms between pediatric development and adult degeneration.

Together, these studies paint a full-spectrum picture of NLD development and dysfunction across the lifespan. The current study uniquely contributes fine-grained, age-specific anatomical data, bridging gaps in the literature and enhancing the foundation for pediatric lacrimal disorder management.

8. LIMITATIONS AND FUTURE DIRECTIONS

While this retrospective study utilized a robust sample size and detailed statistical analysis, it is not without limitations. The use of CT scans obtained for other clinical reasons may introduce selection bias. Also, as a cross-sectional study, it does not track longitudinal changes in individuals, which could offer more precise growth trajectories. Future research should consider longitudinal studies and include a larger sample in each subgroup to validate and extend these findings

9. STUDY LIMITATION

- The study has been observed on patients visiting TMU hospital in department of Radiological imaging.
- The study has been conducted on 0-20 age group only.

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