Aortic valve cusp growth in dilated tricuspid aortic roots

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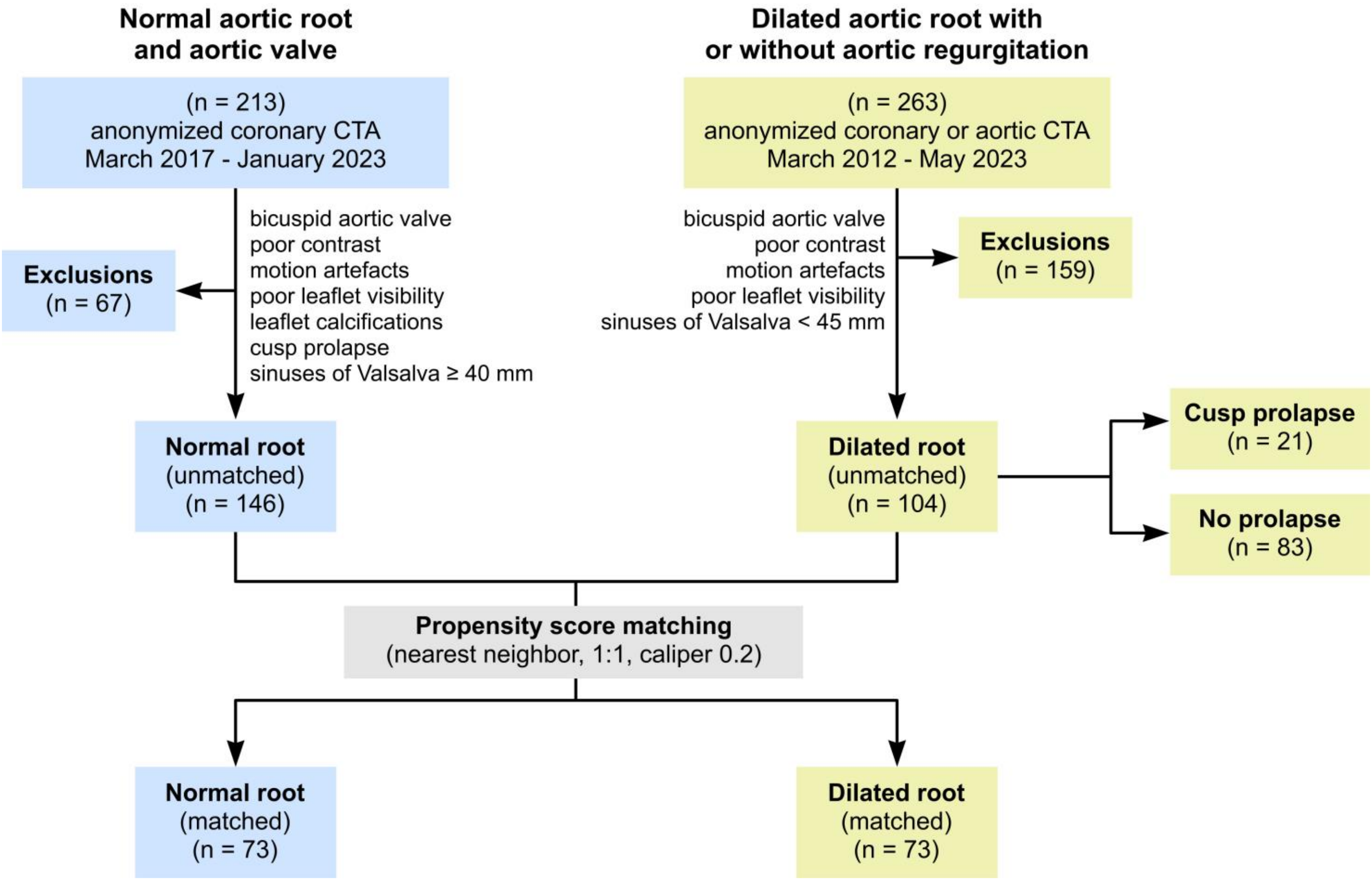
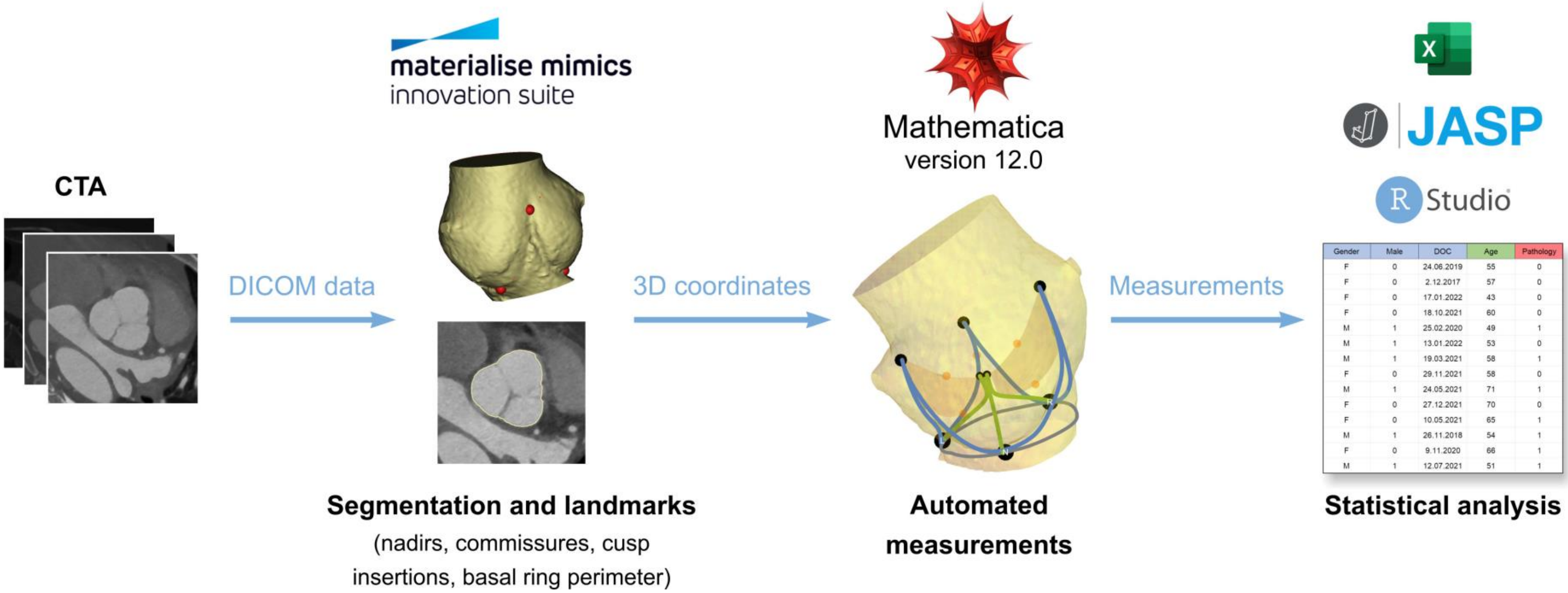
Objectives

- Valve-preserving root replacement aims at normalizing valve form through restoration of root dimensions
- In patients with aortic root aneurysm, the cusps may change in size and shape due to stress imposed by root dilatation
- The purpose of this study was to quantify the differences in cusp size and shape in patients with normal and dilated tricuspid aortic roots and in dilated roots with or without aortic regurgitation

Patients


Normal aortic root
and aortic valve
(n = 213)
anonymized coronary CTA
March 2017 - January 2023
bicuspid aortic valve
poor contrast
motion artefacts
poor leaflet visibility
leaflet calcifications
cusp prolapse
sinuses of Valsalva ≥ 40 mm
Exclusions
(n = 67)
Normal root
(unmatched)
(n = 146)
Dilated aortic root with
or without aortic regurgitation
(n = 263)
anonymized coronary or aortic CTA
March 2012 - May 2023
bicuspid aortic valve
poor contrast
motion artefacts
poor leaflet visibility
sinuses of Valsalva < 45 mm
Exclusions
(n = 159)
Dilated root
(unmatched)
(n = 104)
Cusp prolapse
(n = 21)
No prolapse
(n = 83)
Propensity score matching
(nearest neighbor, 1:1, caliper 0.2)
Normal root
(matched)
(n = 73)
Dilated root
(matched)
(n = 73)

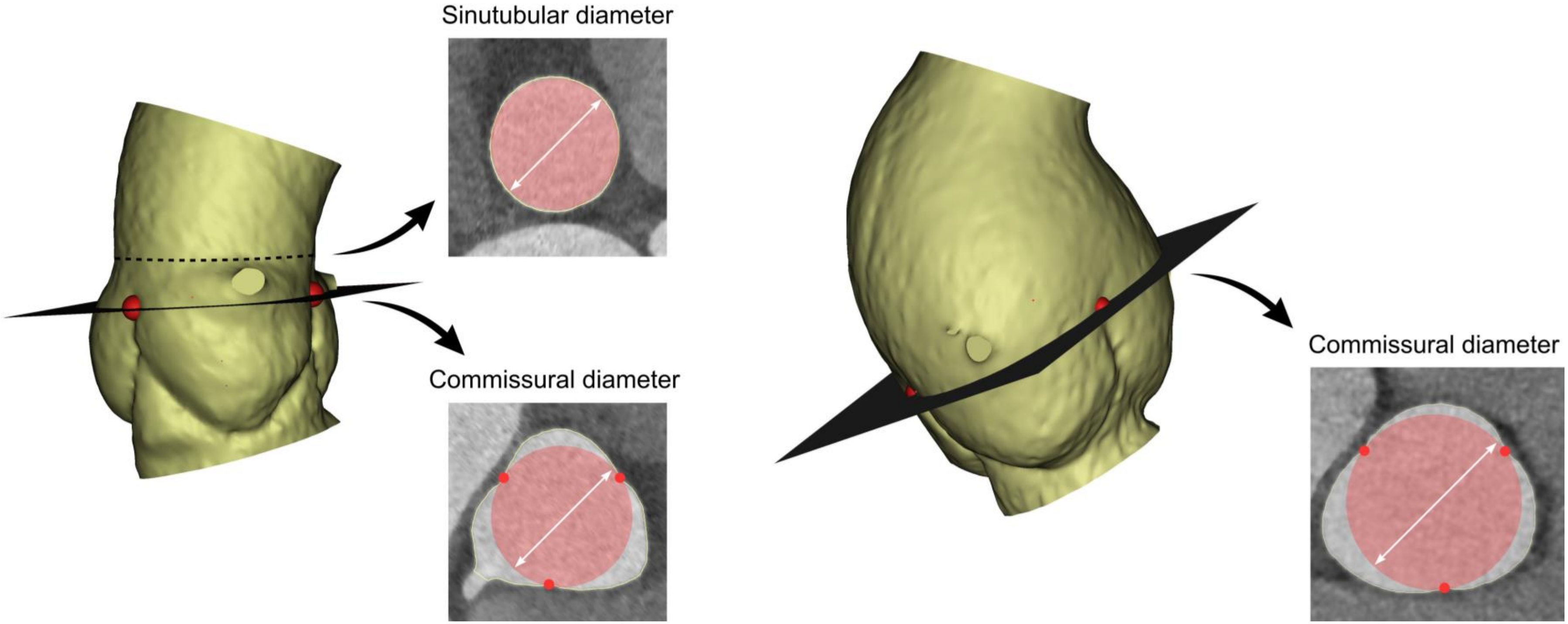
CTA analysis



Gender	Male	DOC	Age	Pathology
F	0	24.06.2019	55	0
F	0	2.12.2017	57	0
F	0	17.01.2022	43	0
F	0	18.10.2021	60	0
M	1	25.02.2020	49	1
M	1	13.01.2022	53	0
M	1	19.03.2021	58	1
F	0	29.11.2021	58	0
M	1	24.05.2021	71	1
F	0	27.12.2021	70	0
F	0	10.05.2021	65	1
M	1	26.11.2018	54	1
F	0	9.11.2020	66	1
M	1	12.07.2021	51	1

Commissural diameter

- Commissural diameter = diameter of a virtual circle passing through the three commissures
- Unlike sinutubular junction, which is often absent in dilated roots, the commissural diameter can be measured in all cases



Propensity score matching

Propensity score matching was used to select patients with comparable age, body size and sex using the available demographic data (age, weight, height, body surface area and sex). Nearest neighbor method of matching was used with ratio of 1:1 and caliper size was set to 0.2 standard deviation of logit of propensity score (MatchIt algorithm, R Foundation for Statistical Computing, Vienna, Austria)

	Unmatched normal root (n = 146)	**Unmatched dilated root (n = 104)**	**P-value**	**Matched normal root (n = 73)**	**Matched dilated root (n = 73)**	**P-value**
Age (years), mean (SD)	56 (13)	54 (13)	0.378[1]	54 (13)	54 (13)	0.870[3]
Male sex	78 (53.4%)	95 (91.3%)	<0.001[2]	63 (86%)	64 (88%)	0.317[4]
Height (cm), mean (SD)	172 (9)	182 (19)	<0.001[1]	178 (8)	178 (9)	0.214[3]
Weight (kg), mean (SD)	77 (16)	91 (16)	<0.001[1]	86 (14)	86 (14)	0.719[3]
BSA (m^2), mean (SD)	1.91 (0.23)	2.14 (0.23)	<0.001[1]	2.05 (0.19)	2.06 (0.19)	0.533[3]

[1]Student‘s t-test, [2]Chi-squared test, [3]Paired samples t-test, [4]McNemar‘s test

Results - root dimensions

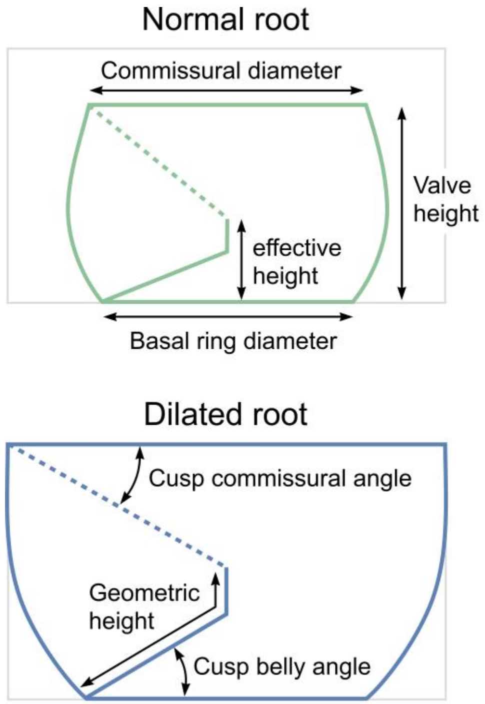


Diagram of mean root dimensions drawn proportionatelly for normal and dilated roots with definitions of different measurements.

	Matched normal roots (n = 73)	Matched dilated roots (n = 73)	P-value
Absolute dimensions			
Basal ring diameter (mm), median (IQR)	26.0 (2.5)	28.3 (4.4)	<0.001[1]
Commissural diameter (mm), median (IQR)	28.8 (2.9)	44.3 (8.1)	<0.001[1]
Sinuses of Valsalva diameter (mm), median (IQR)	35.5 (4.4)	51.1 (5.6)	<0.001[1]
Valve height (mm), median (IQR)	20.8 (1.9)	26.2 (4.3)	<0.001[1]
Root volume (cm^3), median (IQR)	16.5 (3.6)	40.2 (16.3)	<0.001[1]
Dimensions normalized to basal ring diameter			
Normalized commissural diameter, mean (SD)	1.11 (0.10)	1.58 (0.23)	<0.001[2]
Normalized Sinuses of Valsalva diameter, mean (SD)	1.35 (0.11)	1.81 (0.22)	<0.001[2]
Normalized valve height, mean (SD)	0.79 (0.07)	0.92 (0.11)	<0.001[2]

[1]Wilcoxon signed-rank test, [2]Paired samples t-test

Results - cusp dimensions

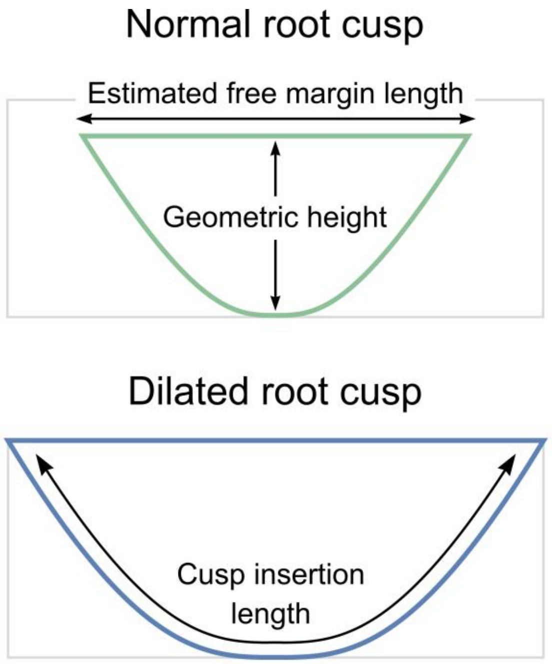


Diagram of mean cusp dimensions drawn proportionatelly for normal and dilated roots with definitions of different measurements.

	Matched normal roots (n = 73)	Matched dilated roots (n = 73)	P-value
Absolute dimensions			
Cusp insertion length (mm), median (IQR)	54.7 (4.5)	71.2 (10.6)	<0.001[1]
Geometric height (mm), median (IQR)	16.7 (1.7)	19.8 (2.3)	<0.001[1]
Estimated free margin length (mm), median (IQR)	36.0 (3.6)	48.1 (7.9)	<0.001[1]
Effective height (mm), median (IQR)	8.7 (1.6)	13.6 (2.9)	<0.001[1]
Cusp belly angle (degrees), mean (SD)	24.3 (5.8)	37.3 (8.4)	<0.001[2]
Cusp commissural angle (degrees), mean (SD)	38.0 (4.5)	29.4 (8.6)	<0.001[2]
Dimensions normalized to cusp geometric height			
Normalized cusp insertion length, mean (SD)	3.26 (0.20)	3.64 (0.39)	<0.001[2]
Normalized estimated free margin length, mean (SD)	2.16 (0.19)	2.53 (0.30)	<0.001[2]
Normalized effective height, mean (SD)	0.53 (0.07)	0.66 (0.10)	<0.001[2]

[1]Wilcoxon signed-rank test, [2]Paired samples t-test

Results - linear regression for cusp geometric height

Multivariable linear regression model with geometric height as the dependent variable was constructed using all (unmatched) patient data (n = 250, adjusted R^2 = 0.847). Commissural diameter was the strongest positive predictor of cusp geometric height, followed by basal ring diameter, body height and male gender. Age had a small negative correlation with geometric height.

Coefficients	**Unstandardized**	**Standard error**	**Standardized**	**t**	**P-value**
(Intercept)	0.623	1.760		0.354	0.724
Commissural diameter (mm)	0.167	0.011	**0.563**	15.728	<0.001
Basal ring diameter (mm)	0.210	0.033	0.264	6.382	<0.001
Height (cm)	0.037	0.010	0.140	3.771	<0.001
Age (years)	-0.021	0.006	-0.097	-3.409	<0.001
Male sex	0.452	0.218	0.073	2.076	0.039

Results - dilated roots and grade of aortic regurgitation

Comparison between dilated roots with mild or no aortic regurgitation (grade 0-1, n = 29) and moderate to severe aortic regurgitation (grade 2-4, n = 54). Cases with single or multiple cusp prolapse were excluded (n = 21). The commissural diameter and effective cusp height were significantly larger in patients with aortic regurgitation, however the cusp dimensions were similar in both groups.

	AR grade 0-1 (n = 29)	AR grade 2-4 (n = 54)	P-value
Basal ring diameter (mm), median (IQR)	29.3 (3.2)	28.1 (4.8)	0.347[2]
Commissural diameter (mm), median (IQR)	41.9 (5.8)	45.0 (6.7)	0.002[2]
Sinuses of Valsalva diameter (mm), median (IQR)	50.6 (4.8)	52.1 (6.3)	0.231[2]
Valve height (mm), median (IQR)	27.2 (4.1)	25.6 (3.4)	0.057[2]
Effective height (mm), median (IQR)	12.7 (2.9)	14.3 (3.0)	0.004[2]
Cusp insertion length (mm), median (IQR)	73.3 (7.5)	71.6 (8.8)	0.381[1]
Geometric height (mm), median (IQR)	20.1 (1.7)	20.5 (2.1)	0.374[1]
Estimated free margin length (mm), median (IQR)	49.0 (6.4)	48.1 (8.0)	0.782[2]
Normalized commissural diameter, mean (SD)	1.44 (0.18)	1.61 (0.21)	<0.001[1]
Normalized effective height, mean (SD)	0.63 (0.08)	0.69 (0.09)	0.005[1]

[1]Student's t-test, [2]Mann-Whitney U-test

Conclusions

- in the dilated roots most of the dilatation occurred at the level of the sinuses of Valsalva and the commissures, and it was associated with mild root elongation
- cusps in dilated roots were elongated transversely (increasing free margin lengths and cusp insertion length) and to a lesser degree radially (increasing the cusp geometric height)
- the most important predictor of cusp geometric height was commissural diameter, which was significantly larger in dilated roots
- in patients with dilated roots and no cusp prolapse the functional aortic regurgitation was caused by extensive commissural dilatation and not by inadequate cusp growth
- changes of cusp dimensions exist in correlation with root size which will have to be accommodated in valve-preserving surgery to produce normal aortic valve form