Advancements in Nasal Cavity Characterization: An Innovative Approach Using CBCT Imaging

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CRIL – Craniofacial Research Instrumentation Laboratory

BACKGROUND

Analyzing a patient's nasal anatomy and airway space holds value for the practices of orthodontics and anesthesiology. Visualizing and measuring the anatomy of this space is possible using existing CBCT images captured for orthodontic treatment planning. Modern computer applications allow for image orientation, superimposition, and analysis. The ability to compare changes in the soft and hard tissue architecture of the nasal cavity provides a valuable tool for use in future studies in the fields of orthodontics and dental anesthesiology. With this project, we aimed to develop a reproducible and reliable protocol for measuring airway features along the inferior nasal passage and validated its utility with a retrospective cohort application.

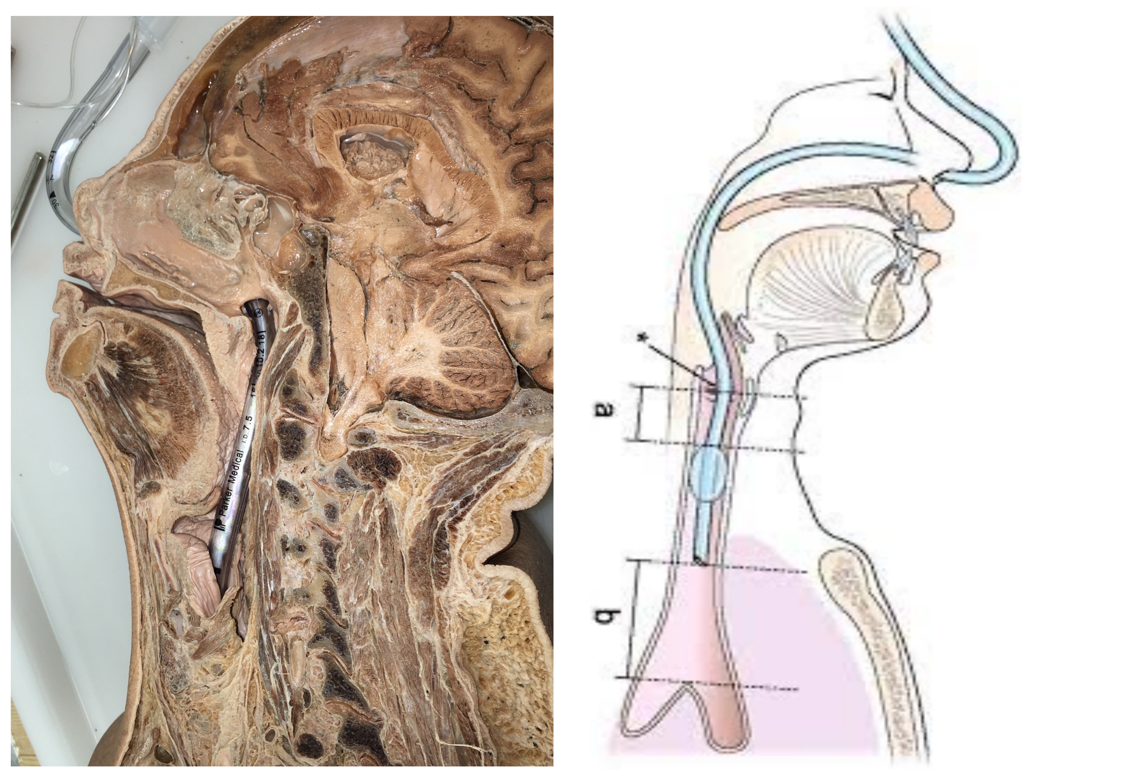

Figure 1. Cadaver demonstration and animation of nasotracheal intubation.

OBJECTIVE

With this project, we aimed to develop a reproducible and reliable protocol for measuring airway features along the inferior nasal passage and validated its utility with a retrospective cohort application.

MATERIAL AND METHODS

ORIENTATION - Conventionally-treated orthodontic patients were selected such that their age was greater than 18 years and orthodontic treatment time ranged from 12 to 36 months. In addition, there was a selective exclusion of syndromic patients, cleft lip and cleft palate patients, and any patients who received any variation of maxillary expansion, orthognathic surgery or nasal surgery or trauma during treatment time. Pre- and post-operative CBCT images, T1 and T2 respectively, were opened in Dolphin Imaging and individually oriented using the anterior nasal spine (ANS), posterior nasal spine (PNS) and orbital rim as landmarks for vertical and horizontal alignment in all three planes. Coronally, the images were aligned such that the horizontal line between the inferior-most portion of each orbital rim was parallel to the horizon (Figure 2). Transversely, the line that runs from the anterior-most point of ANS to the posterior-most point of PNS was vertically aligned such that it was perpendicular to the horizon (Figure 2). In the sagittal plane, ANS and PNS were located again and the line running through each was oriented horizontally parallel to the horizon (Figure 2).

MEASUREMENTS - Once oriented, both T1 and T2 images of each patient were opened simultaneously in the same screen and registered such that the bony structures of the cranial base were superimposed. Figure 2 demonstrates an example of this process with the white pixels representing T1 and the green pixels representing T2. The red box demarcates the structures of the cranial base that we focused the registration on. After verification, each time point was then opened in ITK-SNAP and adjusted for ideal contrast to facilitate data collection. This software allows for simultaneous exploration and measurement of the same slice between images. Figure 3 shows this unique feature. The intersection of the blue lines is at the the same point in all planes in both images. We first located and measured the distance between ANS and PNS and defined the midpoint of this measurement, M-point. The distance was then further divided into quartiles with the 25% measurement labelled A-point and the 75% measurement labelled P-point. At M-point, the width of the hard palate was measured for reference between the two time points. Taking the upwards anterior slant of the nasal cavity into consideration, a novel protocol was constructed such that hard and soft tissues at each point (A, M and P) along the ANS-PNS line could be properly visualized and measured. At each point A, M and P, the measurements were taken at 40, 20 and 20 slices above the reference point where the hard palate was measured, respectively. For each patient, a total of 14 different measurements were taken. At each time point and for the right and left nasal cavities, the soft tissue width (STW) of the inferior turbinate and the median airway space (MAS) present between the turbinate and the septum were measured (Figure 4). For each measurement, T2-T1 were compared and analyzed in SPSS with paired student t-test.

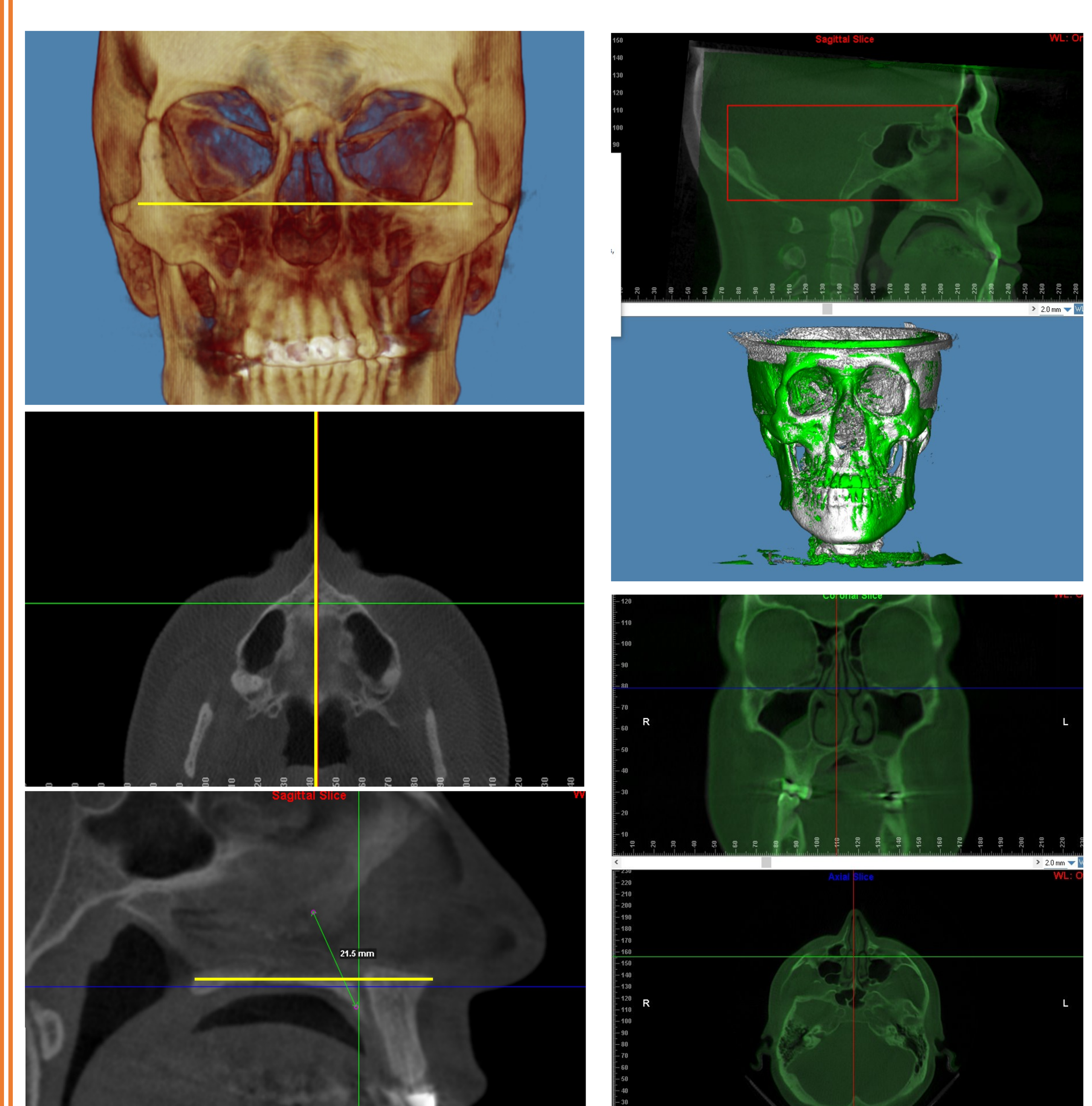

Figure 2. Orientation and registration using Dolphin.

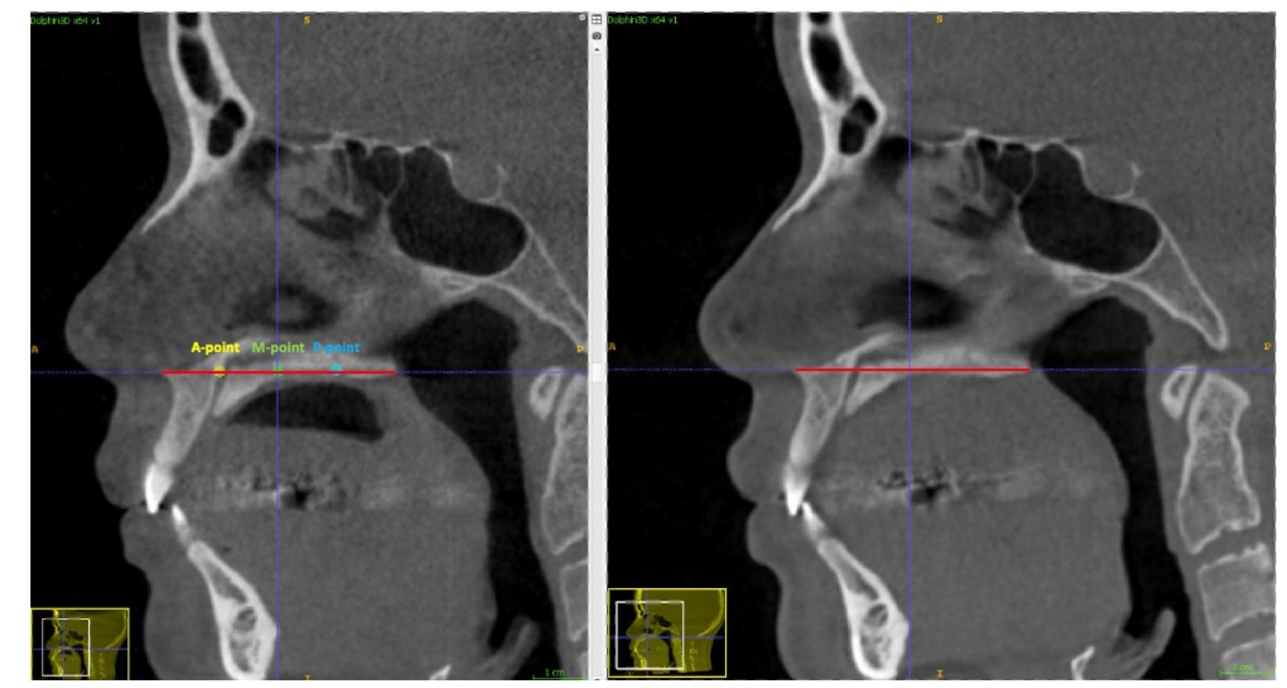

Figure 3. Simultaneous and synchronous measurements in ITK-SNAP.

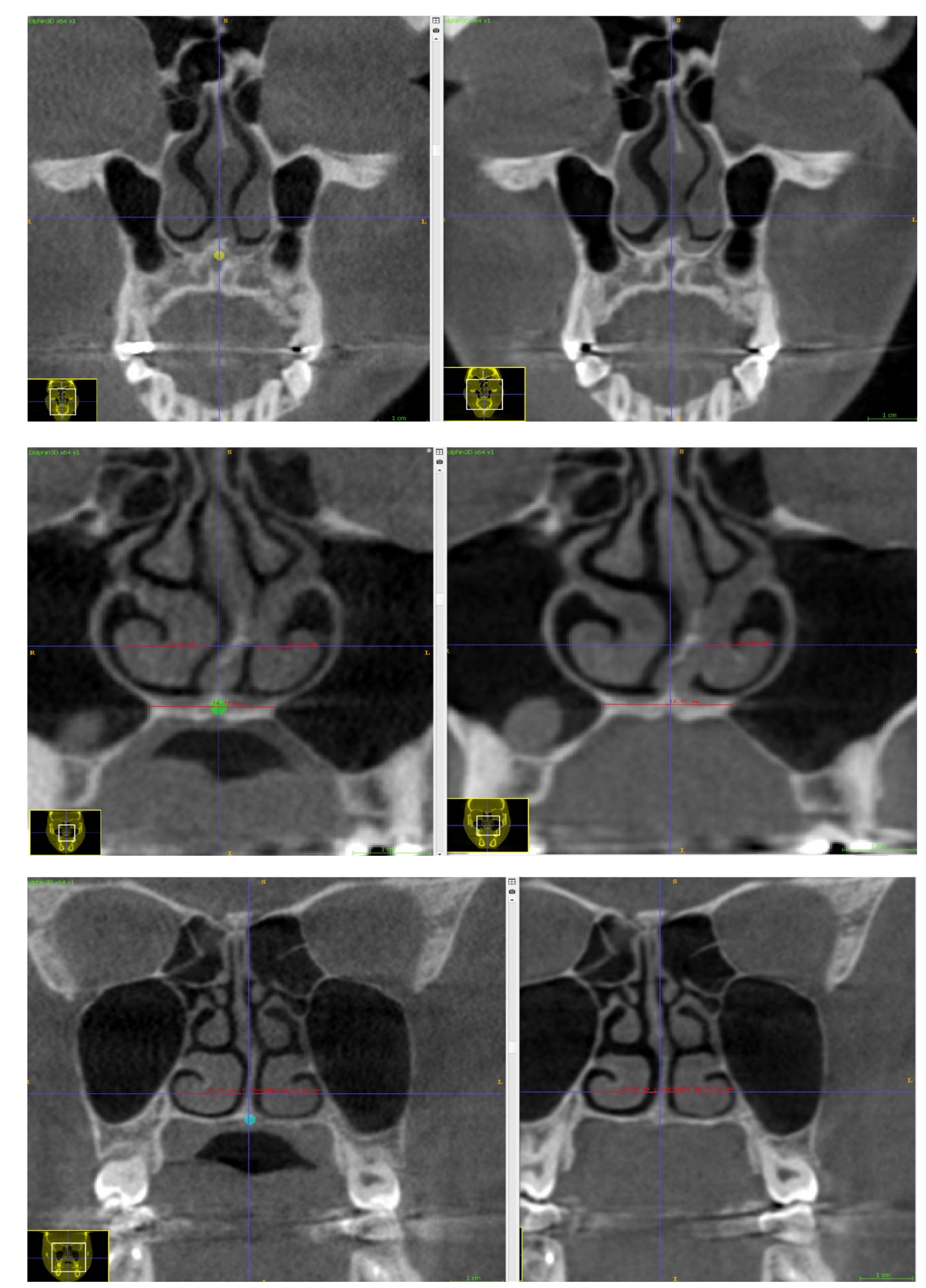

Figure 4. Coronal slices showing nasal cavity anatomy at A-, M- and P-points.

RESULTS

The sample had an average age of 27.2 years with a standard deviation of 8.89 and an average total treatment time of 20.7 months with a standard deviation of 5.08 (Table 1).

The STW and MAS measurements at A-, M- and P- points showed no significant differences between T2-T1 in any of the three regions (Table 2).

age	Mean		27.255	2.6818
	95% Confidence Interval for Mean	Lower Bound	21.279	
		Upper Bound	33.230	
	5% Trimmed Mean		26.794	
	Median		24.000	
	Variance		79.113	
	Std. Deviation		8.8945	
	Minimum		18.0	
	Maximum		44.8	
	Range		26.8	
	Interquartile Range		17.0	
	Skewness		.861	.661
	Kurtosis		-.234	1.279
Months (T1 - T2)	Mean		20.73	1.532
	95% Confidence Interval for Mean	Lower Bound	17.31	
		Upper Bound	24.14	
	5% Trimmed Mean		20.36	
	Median		19.00	
	Variance		25.818	
	Std. Deviation		5.081	
	Minimum		15	
	Maximum		33	
	Range		18	
	Interquartile Range		5	
	Skewness		1.491	.661
	Kurtosis		2.650	1.279

Table 1. Population characteristics data analysis in SPSS.

Paired Samples Test

		Paired Differences							Significance	
					95% Confidence Interval of the Difference					
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	One-Sided p	Two-Sided p
Pair 1	ANS-PNS Length_T1 - ANS-PNS Length_T2	-.22182	.26555	.08007	-.40022	-.04342	-2.770	10	.010	.020
Pair 2	M Point HP Width_T1 - M Point HP Width_T2	-.34455	.26894	.08109	-.52522	-.16387	-4.249	10	<.001	.002
Pair 3	A_STW Left_T1 - A_STW Left_T2	.13636	1.47510	.44476	-.85462	1.12735	.307	10	.383	.765
Pair 4	A_STW Right_T1 - A_STW Right_T2	.17636	1.95887	.59062	-1.13962	1.49235	.299	10	.386	.771
Pair 5	A_MAS Left_T1 - A_MAS Left_T2	.17182	1.11194	.33526	-.57520	.91883	.512	10	.310	.619
Pair 6	A_MAS Right_T1 - A_MAS Right_T2	-.09455	1.46960	.44310	-1.08184	.89275	-.213	10	.418	.835
Pair 7	M_STW Left_T1 - M_STW Left_T2	-.61364	1.96579	.59271	-1.93427	.70700	-1.035	10	.162	.325
Pair 8	M_STW Right_T1 - M_STW Right_T2	-.12909	1.70495	.51406	-1.27449	1.01631	-.251	10	.403	.807
Pair 9	M_MAS Left_T1 - M_MAS Left_T2	.85364	2.42317	.73061	-.77427	2.48154	1.168	10	.135	.270
Pair 10	M_MAS Right_T1 - M_MAS Right_T2	.17364	1.21007	.36485	-.63930	.98657	.476	10	.322	.644
Pair 11	P_STW Left_T1 - P_STW Left_T2	-.26273	1.66821	.50298	-1.38345	.85799	-.522	10	.306	.613
Pair 12	P_STW Right_T1 - P_STW Right_T2	.01727	1.95068	.58815	-1.29321	1.32776	.029	10	.489	.977
Pair 13	P_MAS Left_T1 - P_MAS Left_T2	.13636	1.02560	.30923	-.55265	.82537	.441	10	.334	.669
Pair 14	P_MAS Right_T1 - P_MAS Right_T2	.05273	1.30105	.39228	-.82133	.92679	.134	10	.448	.896

Table 2. Paired t-tests for STW and MAS differences between T2-T1 at each point A, M and P along the ANS-PNS line.

CONCLUSION

We developed a novel protocol for measurement that allows for consistent data acquisition across patient images. We found no statistically significant differences in airway measurements between the two time points. This study represents an important and useful bridge for applications such as determining optimal airway preparation for nasal intubation for general anesthesia as well as providing a new way to examine and analyze the impact of various methods of orthodontic treatment on the soft and hard tissue architecture of the nasal cavity.

AKNOWLEDGEMENTS

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Full name(s) and class year(s) of all project collaborators
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Project Category

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