The Effect of Vitamin C on Tooth Growth in Guinea Pigs

JRB

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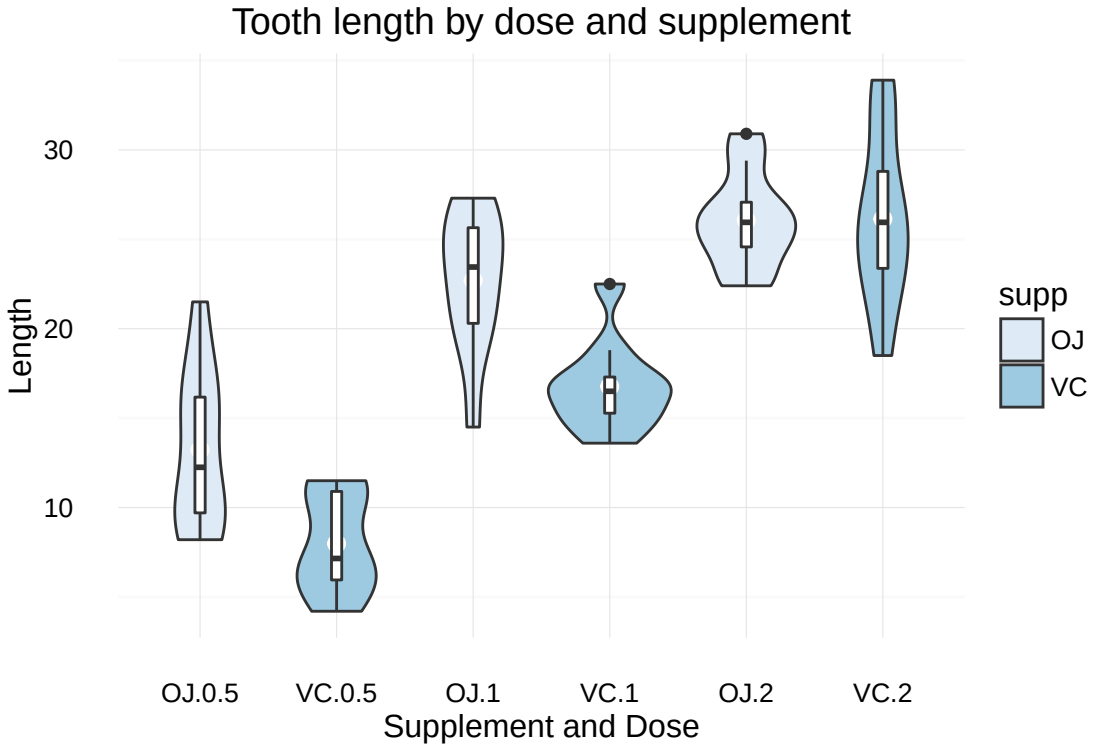
Introduction

We propose to analyze the length of odontoblasts for 60 guinea pigs that have received one of three dose levels of Vitamin C by of of two delivery methods (orange juice OJ) or ascorbic acid (VC). We will first perform some exploratory data analysis to generate some hypothesis that we will be statistically tested.

Exploratory Data Analysis

We fill first plot the data set to represent the density of observations and some key statistics for each combination of delivery method at each dose level. The graph will compare side by side the tooth length for dose level for both OJ and VC.



The figure illustrates that increasing doses of vitamin C would correspond to longer teeth and that the mean of admistration could impact tooth growth also. Table 1 provides a summary of the `ToothGrowth` data set.

From the summary table we can formulate the following hypothesis that could be submitted to a statistical testing. The hypothesis are:

1. Tooth length increases as dose increases
2. Mean of delivery has an impact on tooth growth

Table 1: Summary Statistics for tooth length by dose and supplement

dose	supp	n	Mean	Std.Dev	Sample Error
0.5	OJ	10	13.23	4.46	1.41
0.5	VC	10	7.98	2.75	0.87
1.0	OJ	10	22.70	3.91	1.24
1.0	VC	10	16.77	2.52	0.80
2.0	OJ	10	26.06	2.66	0.84
2.0	VC	10	26.14	4.80	1.52

Hypothesis Testing

Hypothesis 1: "Tooth length increases as dose increases"

To test this hypothesis, we will compare tooth length means at different dose levels (regardless of mean of administration). We will test the null hypothesis that the samples are drawn from populations of the same mean.

Example: Test 1: 0.5 mg vs 1 mg

This section explains our general methodology for hypothesis testing. All results will be summarized in table 2. μ_1 is the mean of tooth length for the 1 mg group
μ_2 is the mean of tooth length for the 0.5 mg group
$H_0 : \mu_1 = \mu_2$, $H_3 : \mu_1 > \mu_2$

First we will calculate our t-statistics (TS) using the R `t.test` function. For our statistical test we assume an unequal variance and a single sided test. We will reject H_0 if $TS \geqslant t_{0.95}$, the $t_{0.95}$ is calculated using 37.99 as the degree of freedom for unequal variances and provided by the `t.test` function. $t_{0.95} = 1.69$. TS is also provided by the R `t.test` function: TS= 6.48. We do have $TS \geqslant t_{0.95}$, and we therefore reject our null hypothesis in favor of the alternate. We conlcude that tooth length is on average greater for the 1mg dose than for the 0.5 mg dose with a 95% confidence.

	Test 1: 0.5 vs 1 mg	Test 2: 1 vs 2 mg	Test 3: 0.5 vs 2 mg
statistic	6.476648	4.900484	11.79905
parameter	37.98641	37.10109	36.88259
p.value	6.341504e-08	9.532148e-06	2.198762e-14

As the previous table show, in all cases the Test Statistics is over the t-value for 0.95 ($t_{0.95} = 1.69$) and the appropriate degree of freedom (df~38). We can appropriately reject H_0. There's a difference in the mean and higer doses have a higher mean than lower doses.

Hypothesis 2: Mean of delivery has an impact on tooth growth

Impact of mean of administration on tooth growth across all dose groups

μ_1 is the mean of tooth length for the OJ group
μ_2 is the mean of tooth length for the VC group

$H_0 : \mu_1 = \mu_2$, $H_3 : \mu_1 > \mu_2$

Table 3: Welch Two Sample t-test: `len` by `supp`

Test statistic	df	P value	Alternative hypothesis
1.9	55	0.03 *	greater

The t-value ($t_{0.95}$) with 55.31 degree of freedom is 1.67. The $t_{0.95}$ value is less than the test statistics so we can reject the null hypothesis.
Conclusion When analyzed across dose groups the mean of administration does have an impact on tooth growth. We will now refine our analysis and look at the tooth length mean differences at each dose level comparing the two means of administration.

Mean of admistration impact by dose level

μ_1 is the mean of tooth length for the OJ group at the analysed dose level
μ_2 is the mean of tooth length for the VC group at the analysed dose level

$H_0 : \mu_1 = \mu_2$, $H_3 : \mu_1 > \mu_2$

Table 4: Table continues below

	len vs. supp at 0.5 mg	len vs. supp at 1 mg
statistic	3.169733	4.03277
parameter	14.96875	15.35767
p.value	0.003179303	0.0005191879

	len vs. supp at 2 mg
statistic	-0.0461361
parameter	14.03982
p.value	0.5180742

At the 0.5 mg and 1 mg dose level, we accept the alternate hypothesis, $\mu_1 > \mu_2$ ($p < \alpha$). At the 2 mg level we do not reject the null hypothesis.
Conclusion At the 0.5mg and 1mg dose level, OJ has a greater mean tooth length than VC. At this dose level the mode of administration has an impact on tooth growth. At the 2 mg level the mean tooth length for OJ and VC is the same.

Conclusion and notes on assumptions

During our analysis we assumed that the samples were iid, the sample variances were considered unequal and we used a confidence level of 95% for all statistical testing. With the statistical rigor of our hypothesis testing we can conclude that:

1. As the dose of vitamin C increases so does the length of the tooth. Vitamin C has a positive impact on the tooth growth of guinea pig

2. The mean of admnistration Orange Juice or Ascorbic Acid has an impact on two growth overall. The impact is measurable for the lower dose groups (0.5mg and 1mg) and favors orange juice over ascorbic acid

Appendix

Additional Summary Tables

Table 6: Summary statistics for tooth length by supplement

supp	n	Mean	Std.Dev	Sample Error
OJ	30	20.66333	6.61	1.21
VC	30	16.96333	8.27	1.51

Table 7: Summary statistics for tooth length by dose

dose	n	Mean	Std.Dev	Sample Error
0.5	20	10.605	4.50	1.01
1.0	20	19.735	4.42	0.99
2.0	20	26.100	3.77	0.84