The Effect of Vitamin C on Tooth Growth in Guinea Pigs

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Introduction

In this short analysis, we explore the effects of vitamin C on the length of odontoblasts (cells responsible for tooth growth) in 60 guinea pigs. Each animal received one of three dose levels of vitamin C (0.5, 1, and 2 mg/day) by one of two delivery methods: orange juice (OJ) or ascorbic acid (a form of vitamin C and coded as VC).

Exploratory analysis

A first look at the data reveals 3 columns. The first one containing the length of the odontoblasts, the second one the delivery method and third the dose of vitamin C.

```
library(datasets)
str(ToothGrowth)
```

```
## 'data.frame':    60 obs. of  3 variables:
##  $ len : num  4.2 11.5 7.3 5.8 6.4 10 11.2 11.2 5.2 7 ...
##  $ supp: Factor w/ 2 levels "OJ","VC": 2 2 2 2 2 2 2 2 2 2 ...
##  $ dose: num  0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 ...
```

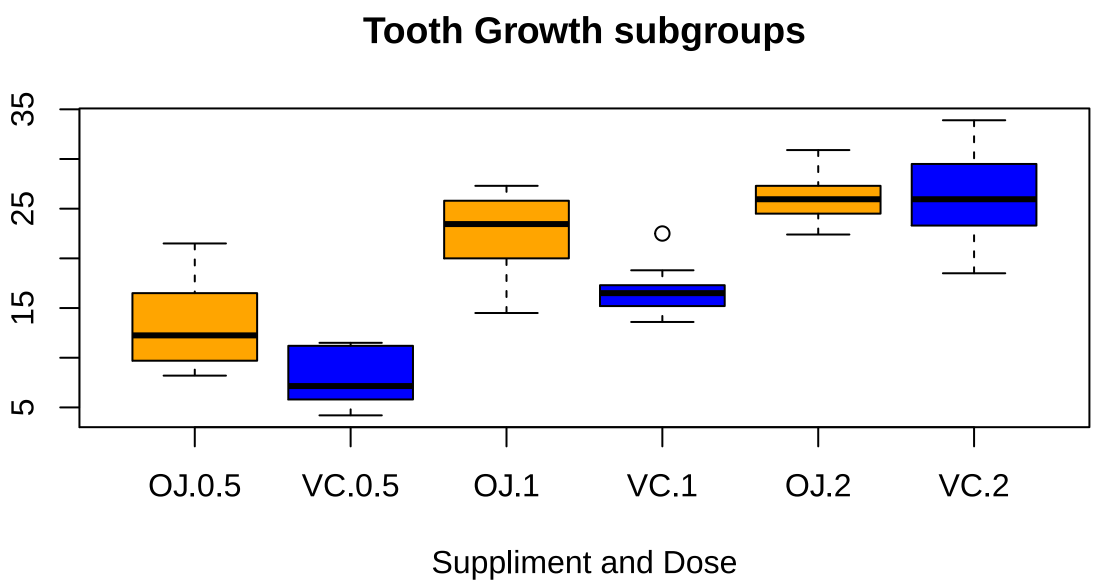
A quick summary reveals that the sample can be groupen in two equal groups by delivery method (OJ and VC). The mean length is 18.81 microns, but the spread goes from 4.20 to 33.90 microns.

```
summary(ToothGrowth)
```

```
##       len        supp         dose      
##  Min.   : 4.20   OJ:30   Min.   :0.500  
##  1st Qu.:13.07   VC:30   1st Qu.:0.500  
##  Median :19.25           Median :1.000  
##  Mean   :18.81           Mean   :1.167  
##  3rd Qu.:25.27           3rd Qu.:2.000  
##  Max.   :33.90           Max.   :2.000  
```

Lets group the sample by different dose and delivery method:

```
boxplot(len~supp*dose, data=ToothGrowth, col=(c("orange","blue")),
        main="Tooth Growth subgroups", xlab="Suppliment and Dose")
```



From this first exploratory analysis, we can formulate a few questions, which we will address in the next section.

- Does a higher dose result in a higher length?
- Does the delivery method influence the growth in general?
- Does the delivery method influence the growth for each dose level?

Hypothesis testing

Influence of delivery method

Let's start with checking if the delivery method has an influence on the length. For this, we split the sample by delivery method. Our null hypothesis is that the delivery method has no influence. We can do a two-sided test to check if the null hypothesis should be accepted or rejected. Since the group size is relatively small (30), we use the t-test. All Guinea pigs are different, so we take the unpaired test. Here's the full output:

```
groups_supp  <- split(ToothGrowth$len, ToothGrowth$supp)
t.test(groups_supp$OJ, groups_supp$VC, alternative = "two.sided", paired = FALSE)
```

```
##
##  Welch Two Sample t-test
##
## data:  groups_supp$OJ and groups_supp$VC
## t = 1.9153, df = 55.309, p-value = 0.06063
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -0.1710156  7.5710156
## sample estimates:
## mean of x mean of y
##  20.66333  16.96333
```

The p-value is larger than 0.05, and we see that a mean differnce of zero lies within the 95 % confidence interval. At the 95 % confidence level, we should accept the null hypothesis.

Influence of dose

We can now test whether a higher dose of vitamin C results in longer odontoblasts. To this end, we test the difference between the extremes. i.e., we group the sample by dose, and check the 0.5 mg/day group against the 2 mg/day group. Our null hypothesis is that dose does not influence length. The alternative hypothesis is that the 0.5 mg/day group has a lower average length. We should again use a t-test to evaluate our hypothesis, but this time a one-sided test.

```
groups_dose  <- split(ToothGrowth$len, ToothGrowth$dose)
pval <- t.test(groups_dose$`0.5`, groups_dose$`2`,
               alternative = "less", paired = FALSE)$p.value
```

The p-value for this test is $2.1987625 \times 10^{-14}$, which is very small. We can thus safely reject the null hypothesis and state that a higher dose indeed results in longer odontoblasts.

Influence of dose and delivery

As a final test, we split the sample by dose and by delivery method. This gives us 6 groups, and we will compare the delivery method for each dose in a two-sided t-test.

```
groups_all  <- split(ToothGrowth$len, list(ToothGrowth$supp,ToothGrowth$dose))

conf0_5 <- t.test(groups_all$OJ.0.5, groups_all$VC.0.5,
                  alternative = "two.sided", paired = FALSE)$conf
conf1 <- t.test(groups_all$OJ.1, groups_all$VC.1,
                alternative = "two.sided", paired = FALSE)$conf
conf2 <- t.test(groups_all$OJ.2, groups_all$VC.2,
                alternative = "two.sided", paired = FALSE)$conf
```

For the dose of 0.5 mg/day, we find a 95 % confidence interval of [1.7190573, 8.7809427].

For the dose of 1.0 mg/day, we find a 95 % confidence interval of [2.8021482, 9.0578518].

For the dose of 2.9 mg/day, we find a 95 % confidence interval of [-3.7980705, 3.6380705].

This suggests that the delivery method does have an influence on the length, but only for the low and intermediate dose. Together with the figure shown in the first section, it is clear that OJ is more effective than VC. But this effect is no longer significant at the highest dose.

Conclusions

Our main conclusions are:

- On a general level (not looking at the dose), the delivery method has no influence on the length of odontoblasts.
- Higher doses of vitamin C (irrespective of the delivery method) result in higher length for the odontoblasts.
- Split by dose and delivery method, we find that at low and intermediate dose, the OJ method causes significantly longer odontoblasts. At the highest dose, the difference between OJ and VC is no longer significant.