Effect of Vitamin C Delivery Methods and Dosage on Tooth Growth in Guinea Pigs

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Overview

The ToothGrowth (https://stat.ethz.ch/R-manual/R-devel/library/datasets/html/ToothGrowth.html) dataset investigates the effect of vitamin C on tooth growth in 60 guinea pigs. IT consists of response (tooth length), delivery methods (supp) and dosage of vitamin C (dose).

```
data("ToothGrowth")
tooth <- ToothGrowth
str(tooth)
```

```
## '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 ...
```

Exploratory Data Analysis

Data Summary

Tooth length (len) is a numerical data where as delivery methos (supp) and dosage of vitamin C (dose) are categorical variables. Dosage consists of only 0.5, 1.0, 2.0 so it is more suitably treated as categorical variable.

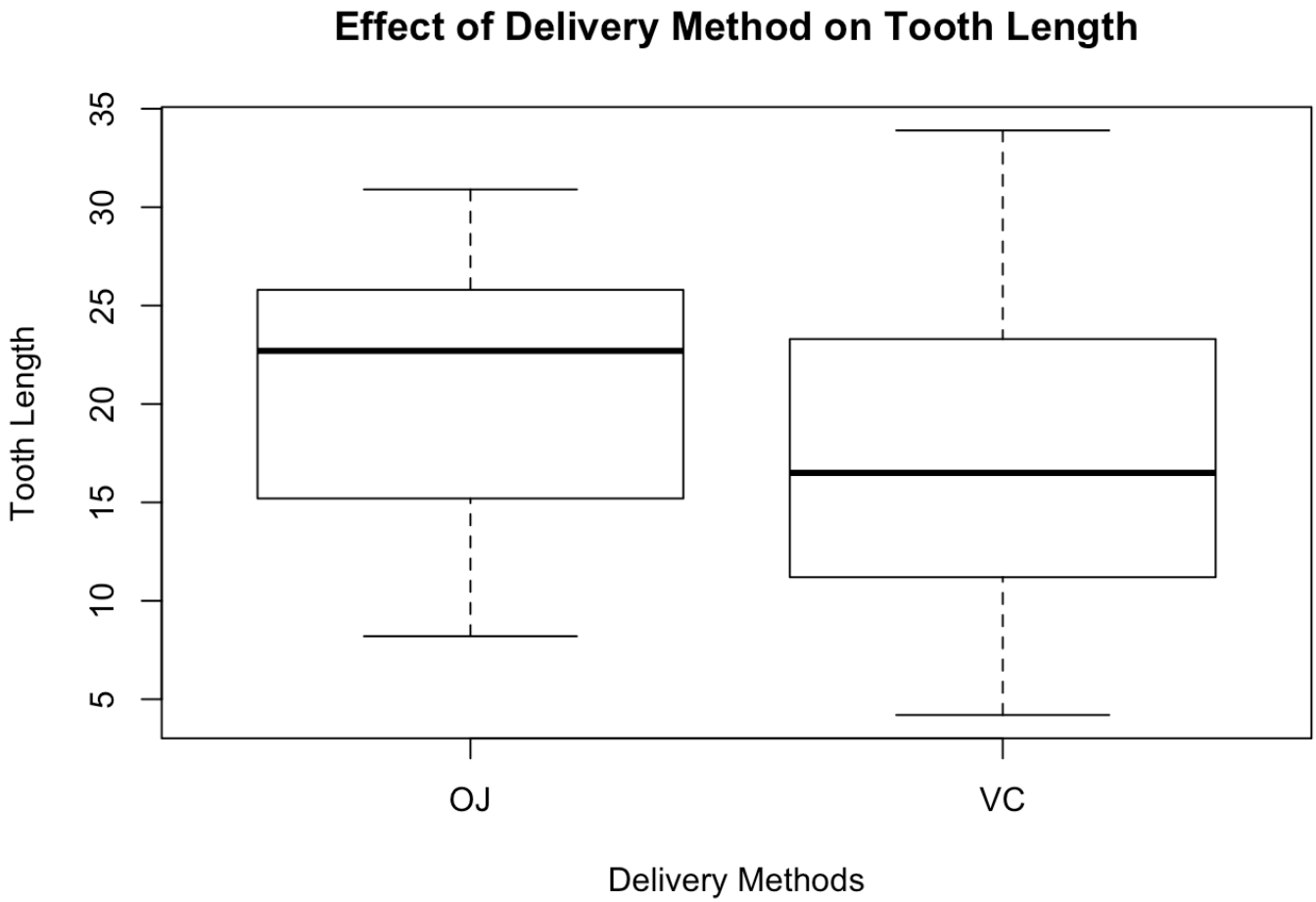
```
summary(tooth)
```

```
##       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
```

Delivery Methods

Regarding tooth length, OJ has a a higher mean than VC, whereas VC has higher variability.

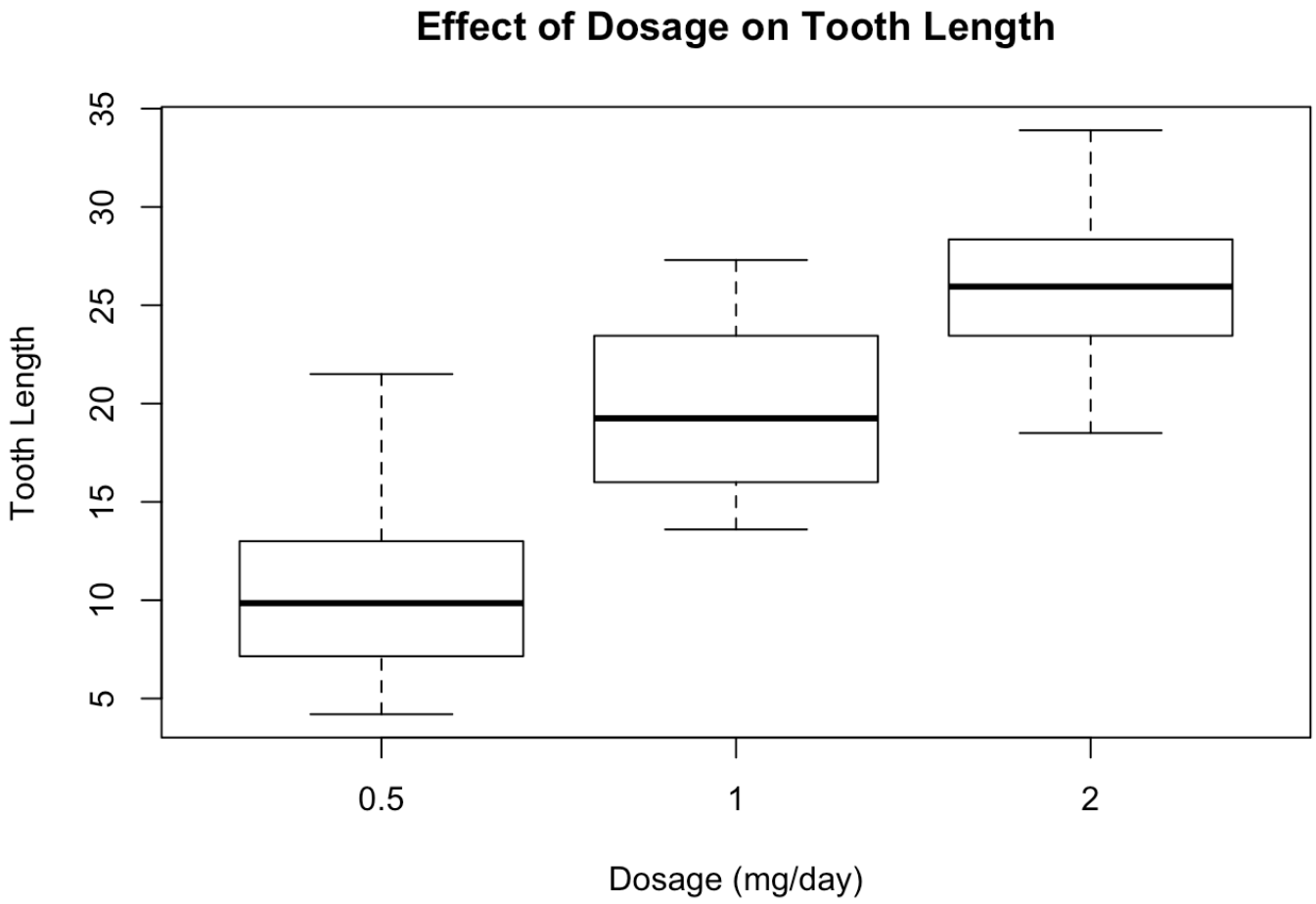
```
plot(x=tooth$supp,y=tooth$len, main='Effect of Delivery Method on Tooth Length',
     xlab='Delivery Methods',ylab='Tooth Length')
```



Dosage

More dosage correlates with longer tooth length.

```
plot(x=as.factor(tooth$dose),y=tooth$len,main='Effect of Dosage on Tooth Length',
     xlab='Dosage (mg/day)',ylab='Tooth Length')
```



Hypothesis Tests and Confidence Intervals

We perfrom unpaired t-tests with unequal variances to find out if different delivery methods and dosage have different effects on tooth length, also providing confidence intervals at 95%.

Delivery Methods

Hypothesis 1

H0: Mean tooth lengths are equal for both OJ and VC

H1: Not H0

Two-sided test has a p-value of 0.061, thus does not reject the null hypothesis. The 95% confidence interval (difference of means) is (-0.1710156,7.5710156). Thus, the effects of delivery methods on tooth length are different on a statistically significant level.

```
t.test(data=tooth,len~supp,paired=FALSE,var.equal=FALSE)
```

```
##
##  Welch Two Sample t-test
##
## data:  len by supp
## 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 in group OJ mean in group VC
##         20.66333         16.96333
```

Dosage

Hypothesis 2.1

H0: Mean tooth length for 0.5 dose is less than that of 1.0

H1: Not H0

```
t.test(data=tooth[tooth$dose==0.5|tooth$dose==1.0,],len~dose,paired=FALSE,var.equa
l=TRUE,alternative='less')
```

```
##
##  Two Sample t-test
##
## data:  len by dose
## t = -6.4766, df = 38, p-value = 6.331e-08
## alternative hypothesis: true difference in means is less than 0
## 95 percent confidence interval:
##       -Inf -6.753344
## sample estimates:
## mean in group 0.5   mean in group 1
##            10.605            19.735
```

Two-sided test has a p-value of 6.331E-08, thus rejects the null hypothesis. The 95% confidence interval (difference of means) is (-Inf,-6.753344). Thus, the 0.5 does has less effect on tooth growth than 1.0 dose.

Hypothesis 2.2

H0: Mean tooth length for 1.0 dose is less than that of 2.0

H1: Not H0

```
t.test(data=tooth[tooth$dose==1.0|tooth$dose==2.0,],len~dose,paired=FALSE,var.equa
l=TRUE,alternative='less')
```

```
##
##  Two Sample t-test
##
## data:  len by dose
## t = -4.9005, df = 38, p-value = 9.054e-06
## alternative hypothesis: true difference in means is less than 0
## 95 percent confidence interval:
##       -Inf -4.175196
## sample estimates:
## mean in group 1 mean in group 2
##          19.735          26.100
```

Two-sided test has a p-value of 9.054E-06, thus rejects the null hypothesis. The 95% confidence interval (difference of means) is (-Inf,-4.175196). Thus, the 1.0 does has less effect on tooth growth than 2.0 dose.

Dosage Controlled by Delivery Methods

We now control for delivery methods and repeat the tests in the previous section.

Dosage When Delivered by OJ

Hypothesis 3.1

H0: Mean tooth length for 0.5 dose is less than that of 1.0 when delivered by OJ

H1: Not H0

```
t.test(data=tooth[tooth$supp=='OJ'&(tooth$dose==0.5|tooth$dose==1.0),],len~dose,pa
ired=FALSE,var.equal=TRUE,alternative='less')
```

```
##
##  Two Sample t-test
##
## data:  len by dose
## t = -5.0486, df = 18, p-value = 4.179e-05
## alternative hypothesis: true difference in means is less than 0
## 95 percent confidence interval:
##       -Inf -6.217322
## sample estimates:
## mean in group 0.5   mean in group 1
##             13.23             22.70
```

Two-sided test has a p-value of 4.179E-05, thus rejects the null hypothesis. The 95% confidence interval (difference of means) is (-Inf,-6.217322). Thus, the 0.5 does has less effect on tooth growth than 1.0 dose when delivered by OJ.

Hypothesis 3.2

H0: Mean tooth length for 1.0 dose is less than that of 2.0 when delivered by OJ

H1: Not H0

```
t.test(data=tooth[tooth$supp=='OJ'&(tooth$dose==1.0|tooth$dose==2.0),],len~dose,pa
ired=FALSE,var.equal=TRUE,alternative='less')
```

```
##
##  Two Sample t-test
##
## data:  len by dose
## t = -2.2478, df = 18, p-value = 0.01868
## alternative hypothesis: true difference in means is less than 0
## 95 percent confidence interval:
##        -Inf -0.7678858
## sample estimates:
## mean in group 1 mean in group 2
##           22.70           26.06
```

Two-sided test has a p-value of 0.01868, thus rejects the null hypothesis. The 95% confidence interval (difference of means) is (-Inf,-0.7678858). Thus, the 1.0 does has less effect on tooth growth than 2.0 dose when deliverd by OJ.

Dosage When Delivered by VC

Hypothesis 4.1

H0: Mean tooth length for 0.5 dose is less than that of 1.0 when delivered by VC

H1: Not H0

```
t.test(data=tooth[tooth$supp=='VC'&(tooth$dose==0.5|tooth$dose==1.0),],len~dose,pa
ired=FALSE,var.equal=TRUE,alternative='less')
```

```
##
##  Two Sample t-test
##
## data:  len by dose
## t = -7.4634, df = 18, p-value = 3.246e-07
## alternative hypothesis: true difference in means is less than 0
## 95 percent confidence interval:
##       -Inf -6.747719
## sample estimates:
## mean in group 0.5   mean in group 1
##              7.98             16.77
```

Two-sided test has a p-value of 3.246E-07, thus rejects the null hypothesis. The 95% confidence interval (difference of means) is (-Inf,-6.747719). Thus, the 0.5 does has less effect on tooth growth than 1.0 dose.

Hypothesis 4.2

H0: Mean tooth length for 1.0 dose is less than that of 2.0 when delivered by VC

H1: Not H0

```
t.test(data=tooth[tooth$supp=='VC'&(tooth$dose==1.0|tooth$dose==2.0),],len~dose,pa
ired=FALSE,var.equal=TRUE,alternative='less')
```

```
##
##  Two Sample t-test
##
## data:  len by dose
## t = -5.4698, df = 18, p-value = 1.699e-05
## alternative hypothesis: true difference in means is less than 0
## 95 percent confidence interval:
##       -Inf -6.399483
## sample estimates:
## mean in group 1 mean in group 2
##           16.77           26.14
```

Two-sided test has a p-value of 1.699E-05, thus rejects the null hypothesis. The 95% confidence interval (difference of means) is (-Inf,-6.399483). Thus, the 1.0 does has less effect on tooth growth than 2.0 dose.

Conclusion

From testing Hypothesis 1-4 we can conclude that:

- Delivery methods do not have differing effects on tooth growth.
- Dosage positively affects tooth growth. This also holds when controlling for delivery methods.

The underlying assumptions for these conclusions are:

- The guinea pigs are randomized to each delivery method and dosage, thus the effect of

confounders are minimized.
- The 60 guinea pigs are representative of the guinea pig population, in order for the our sample results to be generalized.
- We assume unequal variance for t-tests regarding delivery methods whereas we assume equal variance for t-tests regarding dosage (since its just magnitude that changes).