Tooth Growth Analysis

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Overview:

This analysis examines the effects of vitamin C on tooth growth in guinea pigs. Each of the 60 guinea pigs studied received one of three doses of vitamin C per day: 0.5, 1.0, or 2.0 mg/day. There were two delivery methods: orange juice (OJ) and ascorbic acid (VC). The response measures the growth in odontoblasts (cells responsible for tooth growth).

```
# Load dataset
library(datasets)
data("ToothGrowth")

# No scientific notation
options(scipen = 999)
```

First we conduct an exploratory analysis of the "ToothGrowth" dataset. We need to understand the state of our data.

Exploratory analysis

```
# List length of rows / columns
dim(ToothGrowth)
```

```
## [1] 60  3
```

```
# Determine column data types
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 ...
```

```
# Range of tooth growth
range(ToothGrowth$len)
```

```
## [1]  4.2 33.9
```

```
# Levels and counts of delivery methods/supplements
table(ToothGrowth$supp)
```

```
##
## OJ VC
## 30 30
```

```
# Levels and counts of dosages
table(ToothGrowth$dose, ToothGrowth$supp)
```

```
##
##       OJ VC
##   0.5 10 10
```

```
##    1   10 10
##    2   10 10
```

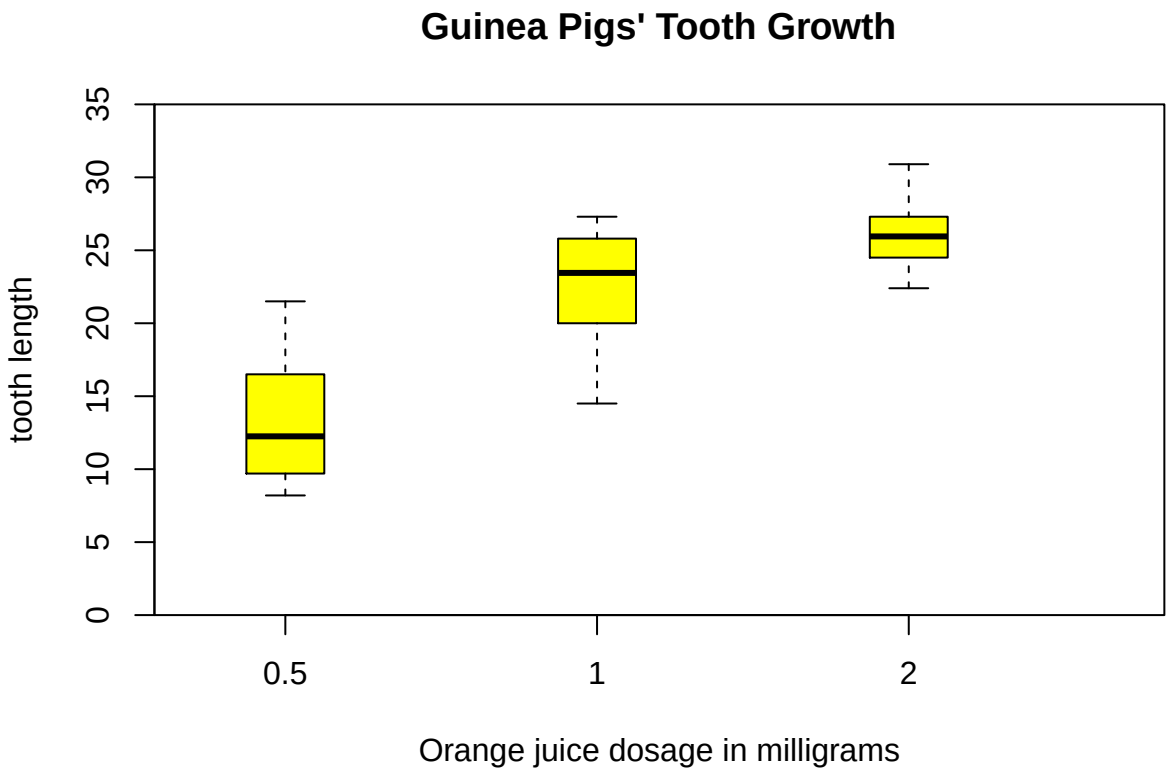
So this appears to be a very tidy data set: 30 guinea pigs were give orange juice and 30 were given ascorbic acid. 10 from each set of guinea pigs were given 0.5, 1.0, or 2.0 milligrams/day of one of the two supplements.

Data summary

So lets take a look at the characteristics of the data related to the 30 guinea pigs given orange juice.

```
# Subset the guinea pigs given orange juice,
# overall and by dosages
oj <- ToothGrowth[ToothGrowth$supp == "OJ",]
oj05 <- oj[oj$dose == 0.5,]
oj10 <- oj[oj$dose == 1.0,]
oj20 <- oj[oj$dose == 2.0,]

# Plot tooth odontoblast length in relation
# to increasing dosages of orange juice.
boxplot(len ~ dose, data = oj,
        boxwex = 0.25, at = 1:3 - 0.2,
        col = "yellow",
        main = "Guinea Pigs' Tooth Growth",
        xlab = "Orange juice dosage in milligrams",
        ylab = "tooth length",
        xlim = c(0.5, 3.5), ylim = c(0, 35), yaxs = "i")
```

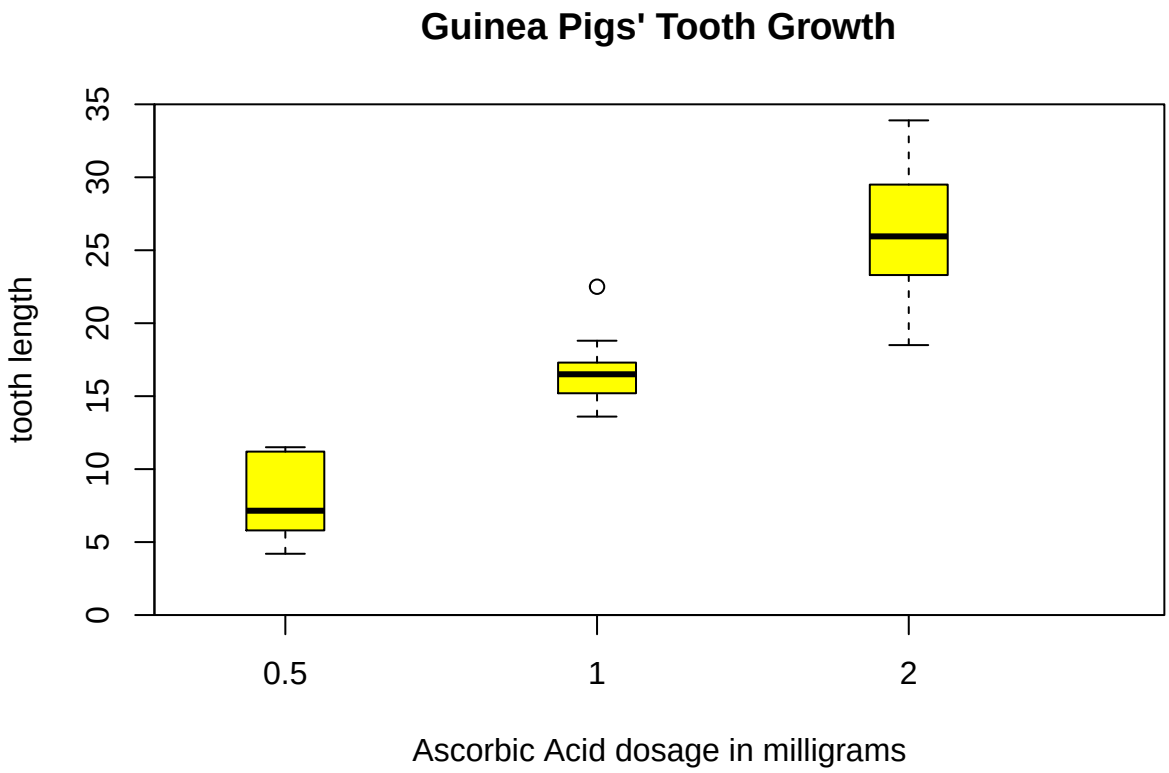


The tooth odontoblast length for the guinea pigs given orange juice appears to increase as dosages increase.

Now we look at the characteristics of the data related to the 30 guinea pigs given ascorbic acid.

```
# Subset the guinea pigs given ascorbic acid,
# overall and by dosages
vc <- ToothGrowth[ToothGrowth$supp == "VC",]
vc05 <- vc[vc$dose == 0.5,]
vc10 <- vc[vc$dose == 1.0,]
vc20 <- vc[vc$dose == 2.0,]

# Plot tooth odontoblast length in relation
# to increasing dosages of ascorbic acid.
boxplot(len ~ dose, data = vc,
        boxwex = 0.25, at = 1:3 - 0.2,
        col = "yellow",
        main = "Guinea Pigs' Tooth Growth",
        xlab = "Ascorbic Acid dosage in milligrams",
        ylab = "tooth length",
        xlim = c(0.5, 3.5), ylim = c(0, 35), yaxs = "i")
```



The tooth odontoblast length for the guinea pigs given ascorbi acid also increases as the dosages increase.

So now we compare tooth growth by supplement and dosage levels.

Comparison of tooth growth by supp and dose

```
# Load libraries
library(knitr)

# Means and standard deviation for the orange
# juice at the three dosage levels
mnsOJ <- rbind(
   c("0.5",mean(oj05$len),round(sd(oj05$len),3),round(var(oj05$len),3)),
   c("1.0",mean(oj10$len),round(sd(oj10$len),3),round(var(oj10$len),3)),
   c("2.0",mean(oj20$len),round(sd(oj20$len),3),round(var(oj20$len),3))
)

# Means and standard error for the ascorbic
# acid samples
mnsVC <- rbind(
  c("0.5",mean(vc05$len),round(sd(vc05$len),3),round(var(vc05$len),3)),
  c("1.0",mean(vc10$len),round(sd(vc10$len),3),round(var(vc10$len),3)),
  c("2.0",mean(vc20$len),round(sd(vc20$len),3),round(var(vc20$len),3))
)

# Display tables of calculated means, sd, variance
kable(mnsOJ, caption = "Orange Juice Means and Variance", col.names = c("Dossage","Mean","Std Dev","Vari
```

Table 1: Orange Juice Means and Variance

Dossage	Mean	Std Dev	Variance
0.5	13.23	4.46	19.889
1.0	22.7	3.911	15.296
2.0	26.06	2.655	7.049

```
kable(mnsVC, caption = "Ascorbic Acid Means and Variance", col.names = c("Dossage","Mean","Std Dev","Va
```

Table 2: Ascorbic Acid Means and Variance

Dossage	Mean	Std Dev	Variance
0.5	7.98	2.747	7.544
1.0	16.77	2.515	6.327
2.0	26.14	4.798	23.018

Tooth growth appears to increase with dosage levels under both supplements but the difference between the two supplements is much more significant at the 0.5 and 1.0 mg/day levels than it is at the 2.0 mg/day level. One concern here would be the increase in the variance of the ascorbic acid sample at the 2.0 dosage level. One would expect it to decrease with an increased dosage level as the orange juice sample did.

Conclusions and assumptions

Lets now compare the guinea pigs' tooth growth under both supplements, and conduct t-test

```r
# Subset the data by dosage level
tg05 <- ToothGrowth[ToothGrowth$dose == 0.5,]
tg10 <- ToothGrowth[ToothGrowth$dose == 1.0,]
tg20 <- ToothGrowth[ToothGrowth$dose == 2.0,]

# At the 1.0 mg/daydosage level
t.test(len ~ supp, paired = F, var.equal = F, data = tg05)
```

```
##
##  Welch Two Sample t-test
##
## data:  len by supp
## t = 3.1697, df = 14.969, p-value = 0.006359
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  1.719057 8.780943
## sample estimates:
## mean in group OJ mean in group VC
##            13.23             7.98
```

```r
# At the 1.0 mg/daydosage level
t.test(len ~ supp, paired = F, var.equal = F, data = tg10)
```

```
##
##  Welch Two Sample t-test
##
## data:  len by supp
## t = 4.0328, df = 15.358, p-value = 0.001038
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  2.802148 9.057852
## sample estimates:
## mean in group OJ mean in group VC
##            22.70            16.77
```

```r
# At the 2.0 mg/daydosage level
t.test(len ~ supp, paired = F, var.equal = F, data = tg20)
```

```
##
##  Welch Two Sample t-test
##
## data:  len by supp
## t = -0.046136, df = 14.04, p-value = 0.9639
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -3.79807  3.63807
## sample estimates:
## mean in group OJ mean in group VC
##            26.06            26.14
```

The first two t-tests clearly reject the null hypotheses that the difference in the mean tooth growth for the guinea pigs given orange juice and the ones given ascorbic acid is non-zero. This is evident by the clearly higher means for the groups given orange juice at the 0.5 and 1.0 mg/day dosage levels. Neither of the confidence intervals for these two t-tests contain zero.

Although the two-sample test result at the 2.0 dosage level seems to reject this same null hypthesis, the

exceptionally high p-value given for this test calls the finding into question. The strength of the evidence to support rejecting the null hypothesis is very low here.

The confidence interval for this test is clearly centered at or near zero, and the mean values for the tooth growth at the 2.0 dosage level is actually higher for the guinea pigs given ascorbic acid. This high variance coupled with the high p-value in the 2.0 dosage level t-test may signal the need for further testing.