Effect of Vitamin C Supplements on Tooth Growth in Guinea Pigs

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Overview

The ToothGrowth data set consists of observations of 60 guinea pigs who each received one of three dose levels of vitamin C (0.5, 1, and 2 mg/day) by one of two delivery methods, (orange juice or ascorbic acid (a form of vitamin C and coded as VC). Each observation measured the length of the odontoblasts (tooth growth) in a sample guinea pig.

Data Exploration

```r
library(datasets)
data(ToothGrowth) ## load ToothGrowth data
str(ToothGrowth)  ## examine quick statistics on data set
```

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

The ToothGrowth data set consists of 60 observations of 3 variables: len (tooth length), supp (supplement type-OJ (orange juice) or VC (Vitamin C)), dose (dosage in mg/day). Let's examine the factors of each variable. Since length is a continuous data measurement, we know there will not be preset unique values. Since dose is a factor and not a measurement, we will transform this variable accordingly.

```r
ToothGrowth$dose <-as.factor(ToothGrowth$dose)
unique(ToothGrowth$supp)
```

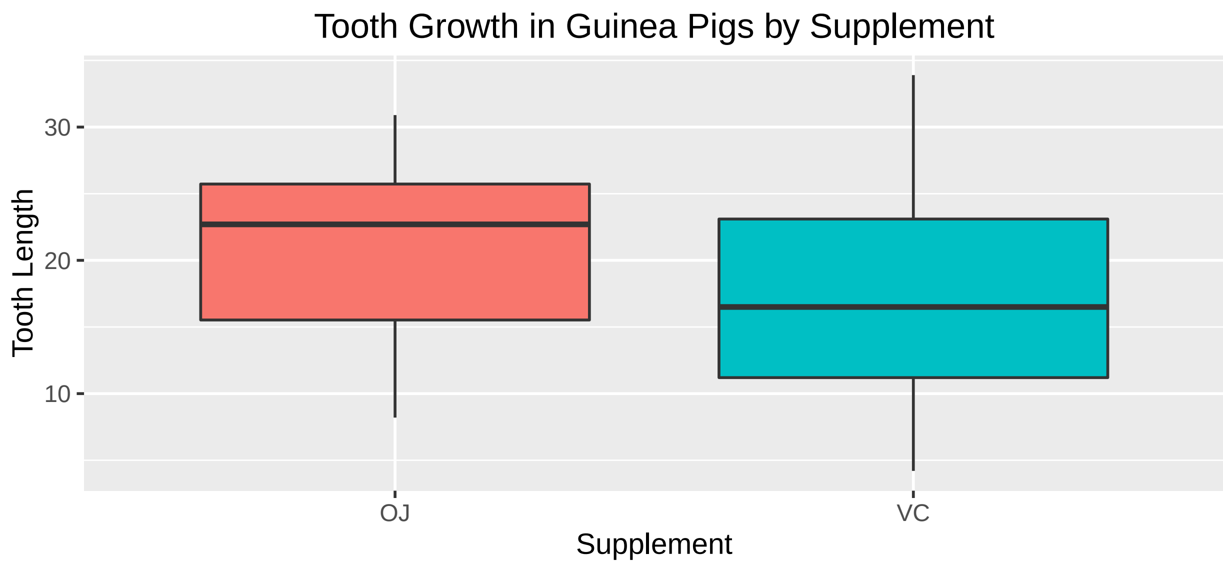
```
## [1] VC OJ
## Levels: OJ VC
```

```r
unique(ToothGrowth$dose)
```

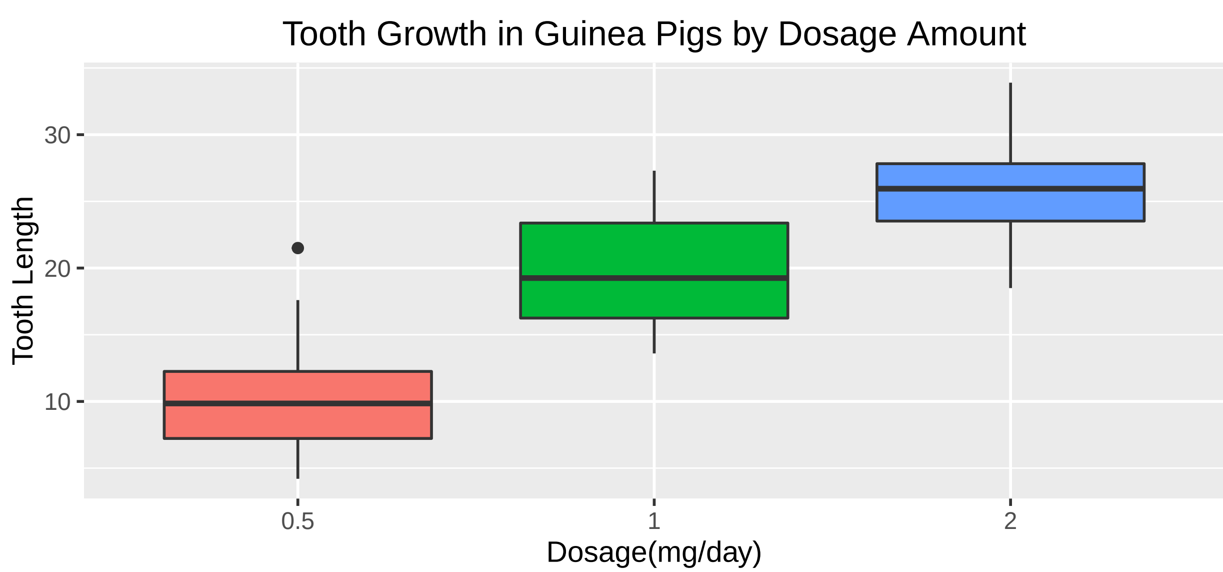
```
## [1] 0.5 1   2
## Levels: 0.5 1 2
```

As expected, test subjects were given either (VC) Vitamin C or (OJ) Ascorbic Acid in doses of either .5, 1.0, or 2.0 mg/day. The data is tidy with no NA values, so no cleaning is necessary. Next, let's examine a boxplot of the data to assess tooth length in terms of supplement and dosage. The boxplot will allow us to visually assess the quartiles of the data. We start with a look at the data on a broad level of supplement type or dosage level

```
library(ggplot2)
ggplot(ToothGrowth, aes(x= supp, y=len, fill = supp)) +geom_boxplot()+
      labs(x="Supplement", y ="Tooth Length",
           title="Tooth Growth in Guinea Pigs by Supplement")+
      scale_fill_discrete(guide=FALSE)
```

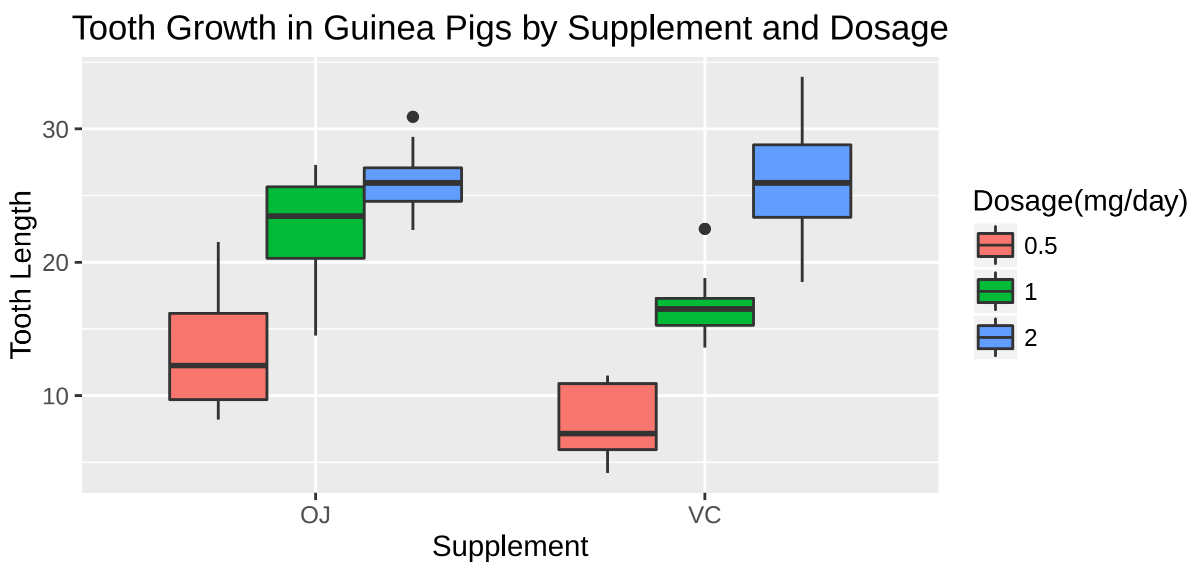



```
ggplot(ToothGrowth, aes(x= factor(dose), y=len, fill = factor(dose))) +geom_boxplot()+
      labs(x="Dosage(mg/day)", y ="Tooth Length",
           title="Tooth Growth in Guinea Pigs by Dosage Amount")+
      scale_fill_discrete(guide=FALSE)
```

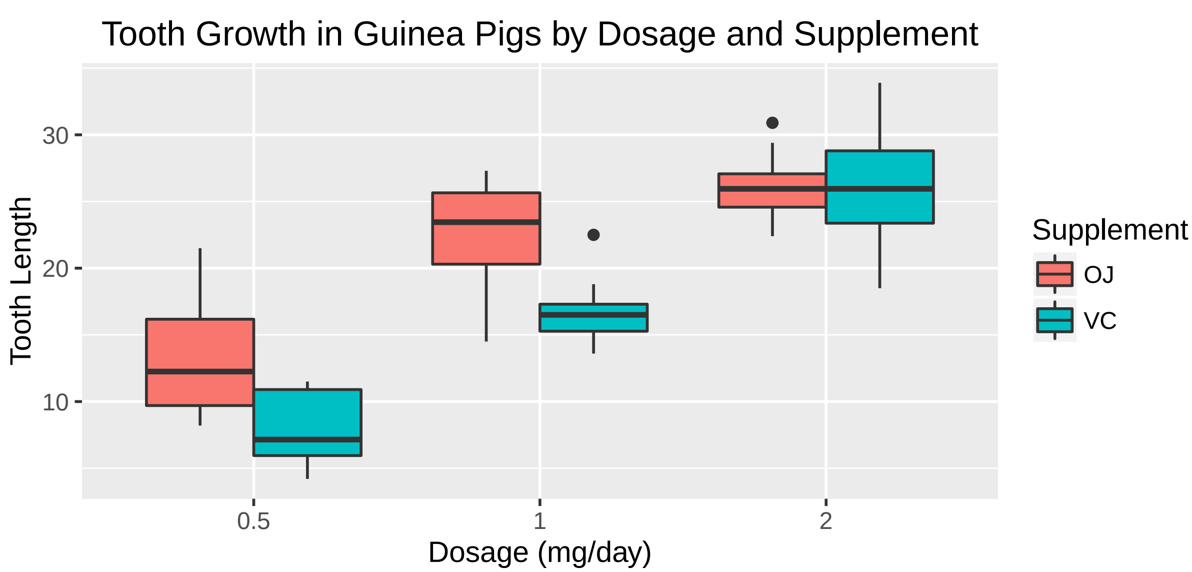


Our visual plot of Supplement Type vs Tooth Length appears inconclusive. The mean and inner two quartiles of OJ are higher than those of VC, but VC has a greater overall range of results. In the second graph, There certainly appears to be a correlation between a higher dosage level and longer tooth length.

```r
ggplot(ToothGrowth, aes(x= supp, y=len, fill = factor(dose))) +geom_boxplot()+
      labs(x="Supplement", y ="Tooth Length",
           title="Tooth Growth in Guinea Pigs by Supplement and Dosage")+
      scale_fill_discrete(name="Dosage(mg/day)")
```




```r
ggplot(ToothGrowth, aes(x= dose, y=len, fill = factor(supp))) +geom_boxplot()+
      labs(x="Dosage (mg/day)", y ="Tooth Length",
           title="Tooth Growth in Guinea Pigs by Dosage and Supplement")+
      scale_fill_discrete(name="Supplement")
```



It would appear that there is a direct correlation between dosage size and tooth growth. Higher dosages resulted in larger tooth sizes for all data. Regarding type of supplement used, OJ seems to promote more growth at lower dosages, while for higher dosages, OJ and VC has roughly equal means while VC has a greater range of values. Accordingly, I will view supplement type as being inconclusive for correlation for now.

Hypothesis Tests and Confidence Intervals

T.Test for supplement type

Visually, we found supplement type to be inconclusive and will set this as our null hypothesis H0 = there is no difference between type of supplement and tooth growth. Due to the small sample size of independent sets, we will use a t.test to attempt to refute our null hypothesis. We will assume the variance between each group is not equal. We will set alpha value to the typical .05, so would need a p-value less than this to justify rejection of our H0.

```
t.test(len ~ supp, paired = F, var.equal=F, data = ToothGrowth)
```

```
##
##  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
```

The t.test yields a t-value of 1.9153, a p-value of .06063, and confidence intervals of -.1710156 and 7.5710156 which contain the zero value. The p-value .06 < alpha (.05) and the confidence intervals contain 0, so we fail to reject H0. Our Null Hypothesis that different supplement types have no effect on tooth length stands.

T.Test for dosage amount

Since a T-test will only compare two variables and we have 3 dosage values, we will need to subset the data for a proper comparison. Three groups cover every possible 2 member group permutation of the three dosage values. Here our null hypothesis H0 = there is no difference between dosage level and tooth growth.

```
library(dplyr)
dose.5 <- filter(ToothGrowth, dose %in% c(0.5,1.0))
dose1 <- filter(ToothGrowth, dose %in% c(0.5,2.0))
dose2 <- filter(ToothGrowth, dose %in% c(1.0,2.0))

dose.5t <- t.test(len ~ dose, paired = FALSE, var.equal=FALSE, data = dose.5)
result1 <- data.frame("p-value"=c(dose.5t$p.value),"Conf-Low"=c(dose.5t$conf[1]),
                      "Conf-High"=c(dose.5t$conf[2]), row.names=c("t.5"), "Dose"="0.5:1.0")
dose.5t
```

```
##
##  Welch Two Sample t-test
##
## data:  len by dose
## t = -6.4766, df = 37.986, p-value = 1.268e-07
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
```

```
##  -11.983781  -6.276219
## sample estimates:
## mean in group 0.5   mean in group 1
##            10.605            19.735
```

```r
dose1t <- t.test(len ~ dose, paired = FALSE, var.equal=FALSE, data = dose1)
result2 <- data.frame("p-value"=c(dose1t$p.value),"Conf-Low"=c(dose1t$conf[1]),
                      "Conf-High"=c(dose1t$conf[2]), row.names=c("t1.0"), "Dose"="0.5:2.0")
dose1t
```

```
##
##  Welch Two Sample t-test
##
## data:  len by dose
## t = -11.799, df = 36.883, p-value = 4.398e-14
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -18.15617 -12.83383
## sample estimates:
## mean in group 0.5   mean in group 2
##            10.605            26.100
```

```r
dose2t <- t.test(len ~ dose, paired = FALSE, var.equal=FALSE, data = dose2)
result3 <- data.frame("p-value"=c(dose2t$p.value),"Conf-Low"=c(dose2t$conf[1]),
                      "Conf-High"=c(dose2t$conf[2]), row.names=c("t2.0"), "Dose"="1.0:2.0")
dose2t
```

```
##
##  Welch Two Sample t-test
##
## data:  len by dose
## t = -4.9005, df = 37.101, p-value = 1.906e-05
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -8.996481 -3.733519
## sample estimates:
## mean in group 1 mean in group 2
##          19.735          26.100
```

For ease of comparison, here is a compilation of p-values and confidence intervals for each subset

```r
resulttable <- rbind(result1, result2, result3)
resulttable
```

```
##           p.value   Conf.Low  Conf.High    Dose
## t.5  1.268301e-07 -11.983781  -6.276219 0.5:1.0
## t1.0 4.397525e-14 -18.156167 -12.833833 0.5:2.0
## t2.0 1.906430e-05  -8.996481  -3.733519 1.0:2.0
```

We find for the subsets that we have p-values so small that they reject our alpha threshold (.05); as well our 3 confidence intervals do not contain 0. Accordingly, we can reject H0 and conclude that in fact, dosage does have an effect on guinea pig tooth growth.

Assumptions

Our conclusions are based on experimentally valid data with such tenets such as 1) observations involved independent subjects (unpaired) 2) the variance between populations tested was unequal 3) the test was done with a random sample from the population 4) samples taken were similar in age and representative of the overall population (tooth length and growth of a 3 month old vs a 1 year old may be radically different)

Conclusions

It would appear from this data set that a higher supplement dosage of Vitamin C directly correlates to increased tooth growth in the guinea pig population. In terms of delivery system, at lower dosages (.5, 1.0 mg/day), data supports orange juice being a delivery method with larger impact than Vitamin C, while at the 2.0 mg/day dosage, results are similar for either delivery method and inconclusive (or there is no further improvement at increased dosages). Further study would be recommended here.