The Effect of Vitamin C on Tooth Growth

Emmanuel Okyere Darko

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Description of data

The response is 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 or ascorbic acid (a form of vitamin C and coded as VC).

Load the ToothGrowth data and perform some basic exploratory data analyses We can also check the datatype of the variables

```
data("ToothGrowth")
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 ...
```

Provide a basic summary of the data.

- We have 3 dose levels, 0.5, 1 and 2 each of 20 quantities were given
- There are 2 delivery methods, VC and OJ, 30 of each were administered
- Tooth length ranges from 4.2 to 33.9 with an average length of 18.81

```
ToothGrowth$dose <- factor(ToothGrowth$dose)
summary(ToothGrowth)
```

```
##       len        supp     dose
##  Min.   : 4.20   OJ:30   0.5:20
##  1st Qu.:13.07   VC:30   1  :20
##  Median :19.25           2  :20
##  Mean   :18.81
##  3rd Qu.:25.27
##  Max.   :33.90
```

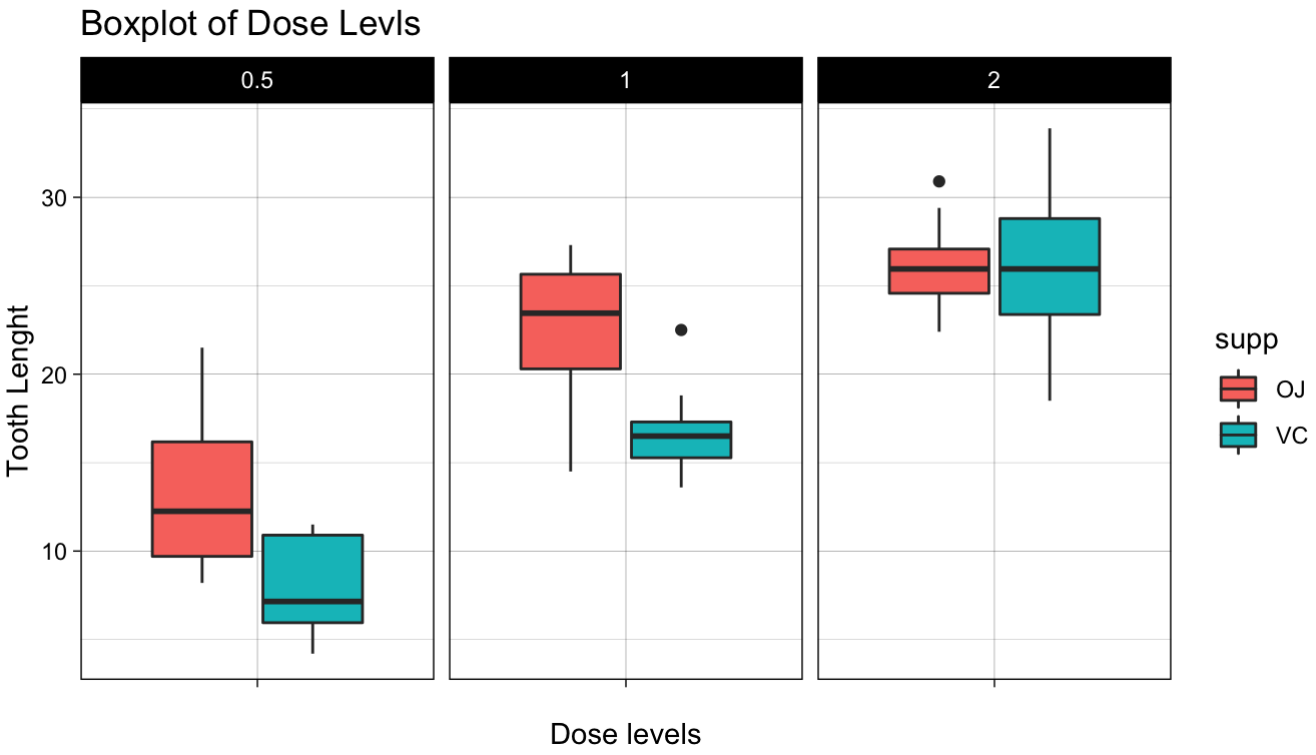
Exploratory Analysis

For every dose level, let's see how tooth leghth varies between the delivery methods.

We can infer that for dose levels of `0.5` and `1`, Orange Juice (OJ) delivery resulted in longer tooth lengths that VC except for dose level `2` where VC delivery had both extreme tooth lengths.

```
library(ggplot2)

ggplot(ToothGrowth) +
 aes(x = "", y = len, fill = supp) +
 geom_boxplot() +
 scale_fill_hue() +
 labs(x = "Dose levels", y = "Tooth Lenght", title = "Boxplot of Dose Levls") +
 theme_linedraw() +
 facet_wrap(vars(dose))
```



Check how many `Dose` were delivery via each method
Equal number of dose were delivered in each case as shown below

```
table(ToothGrowth$supp, ToothGrowth$dose)
```

```
##
##      0.5  1  2
##   OJ  10 10 10
##   VC  10 10 10
```

Hypothesis Testing

Does different supplementary delivery affect Toothgrowth? I will conduct a hypothesis test to answer this question. since the variables are independent, I'll specify `paired = F`

```
with(ToothGrowth, t.test(len~supp, alternative = "two.sided", paired = F))
```

```
##
##  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
```

Here `H0: There's no difference in average tooth-length of supplemetary delivery` . Since the CI `-0.1710156  7.5710156` contains `zero` and also the p-value: `.006` is greater that alpha of `.5` , we fail to reject the null hypothesis in favor of `H0`

tooth-length vs Dose levels

I will create a utility function to subset data

```
tooth_sub <- function(sub){
        return(subset(ToothGrowth, dose %in% sub))
        }


Dose_05_10 <- tooth_sub(c(0.5, 1))
Dose_05_20 <- tooth_sub(c(0.5, 2))
Dose_10_20 <- tooth_sub(c(1, 2))

Dose_05 <- tooth_sub(c(0.5))
Dose_10 <- tooth_sub(c(1))
Dose_20 <- tooth_sub(c( 2))
```

How does average tooth-growth differ in Dose level `.5` and `1`

```
with(Dose_05_10, t.test(len~dose, alternative = "two.sided", paired = F))
```

```
##
##  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
```

Here `H0: There's no difference between dose level .5 average tooth-length and dose level 1.` Since the CI does not contain zero and also the p-value is less than alpha of .5, we reject the null hypothesis in favor of Ha and conclude average Tooth-growth differ

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How does average tooth-growth differ in Dose level `.5` and `2`

```
with(Dose_05_20, t.test(len~dose, alternative = "two.sided", paired = F))
```

```
##
##  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
```

Here `H0: There's no difference between dose level .5 average tooth-length and dose level 2.` Since the CI does not contain zero and also the p-value is less than alpha of .5, we again reject the null hypothesis in favor of Ha and conclude average Tooth-growth differ

---

How does average tooth-growth differ in Dose level `.5` and `1`

```
with(Dose_10_20, t.test(len~dose, alternative = "two.sided", paired = F))
```

```
##
##  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
```

Here `H0: There's no difference between dose level 1 average tooth-length and dose level 2 .` Since the CI does not contain zero and also the p-value is less than alpha of .5, we reject the null hypothesis in favor of Ha and conclude average Tooth-growth differ

For each dose level, how does tooth-growth differ among suplementary delivery?

Here `H0: There's no difference in average tooth-length of supplemetary delivery` for all 3 cases

Does `.5`
The p-value: is less than alpha of .5, we reject the null hypothesis in favor of Ha and conclude average Tooth-growth differ

```
with(Dose_05, t.test(len~supp, alternative = "two.sided", paired = F))
```

```
##
##  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
```

Does `1`
The p-value: is less than alpha of .5, we reject the null hypothesis in favor of Ha and conclude average Tooth-growth differ

```
with(Dose_10, t.test(len~supp, alternative = "two.sided", paired = F))
```

```
##
##  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
```

Does `2`
The p-value: is greater than alpha of `.5` , we fail to reject the null hypothesis
conclude average Tooth-growth does not differ

```
with(Dose_20, t.test(len~supp, alternative = "two.sided", paired = F))
```

```
##
##  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
```

Asumptions

- The sample, in particular guinea pigs is a representative of the population of guinea pigs. This assumption allows us to generalize results
- Guinea pigs were randomly assigned to different levels of dose levels and delivery methods to take care of noise

Conclusion

- Supplementary delivery alone has no effect on the average tooth growth
- For dose levels of `0.5` and `1` , Orange Juice (OJ) delivery resulted in longer tooth lengths that VC except for dose level `2` where VC delivery had both extreme tooth lengths.
- Tooth growth differ between each two dose levels, thus increase in dose level results in increased tooth length