Supplement Effects on Tooth Growth in Guinea Pigs

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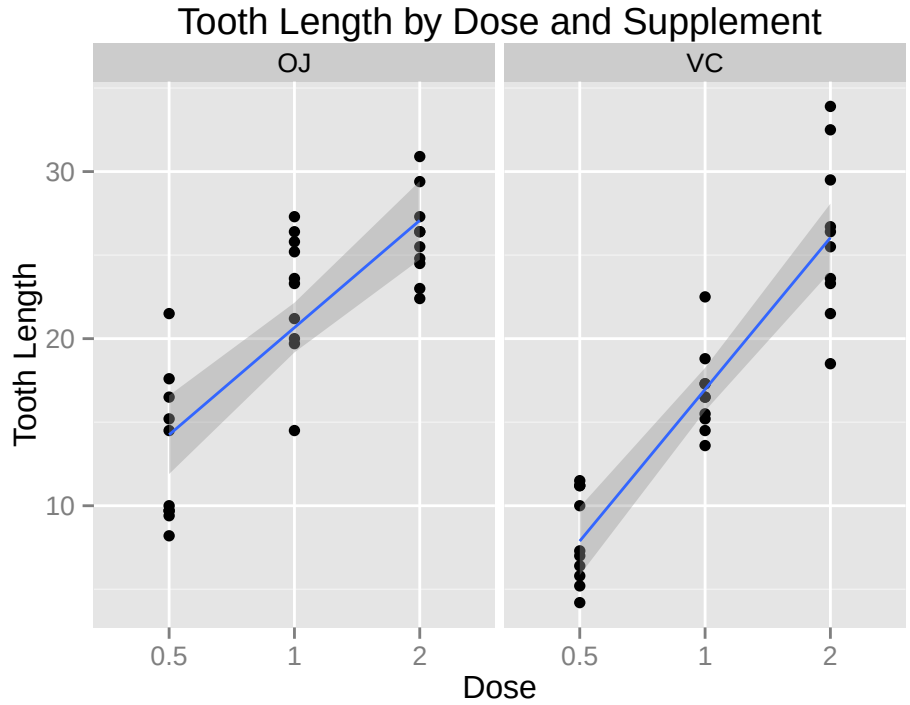
In this analysis, we explore the response of 10 guinea pigs teeth to three dose levels of Vitamin C (0.5, 1 and 2 mg). The dose levels were delivered via two methods: Orange Juice (OJ) or Vitamin C (VC). Which one provided the best response? Keep reading. First, we provide a couple plots to visually see how the data is shaping up.

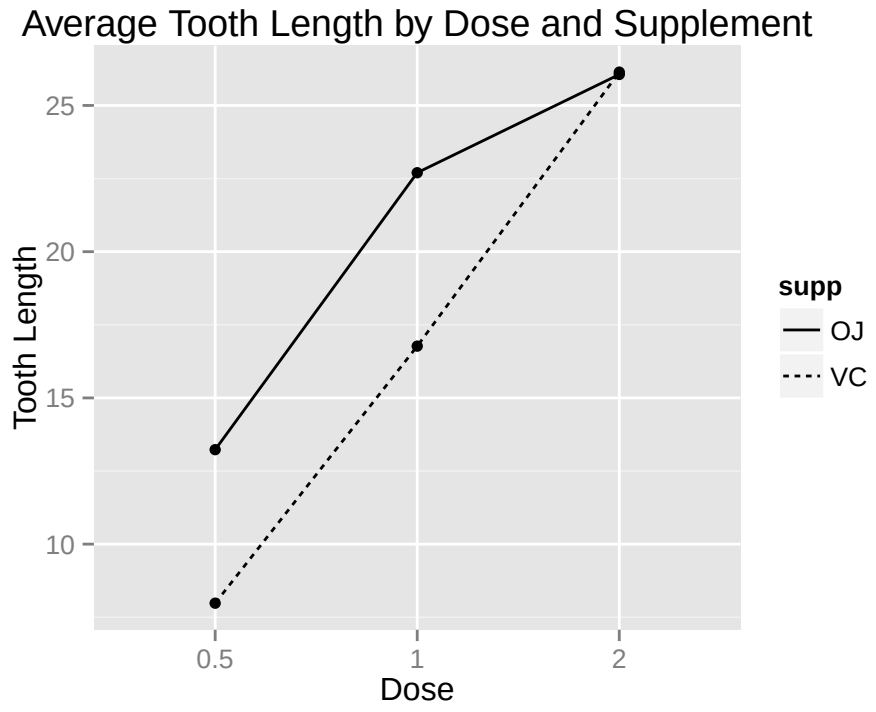
```
library(datasets)
library(ggplot2)

data(ToothGrowth)
tg <- ToothGrowth
tg$dose <- factor(tg$dose)
tgmean <- aggregate(len ~ ., data=tg, mean)

ggplot(tg, aes(x=dose, y=len)) +
    geom_point() +
    geom_smooth(method="lm", aes(group=1)) +
    facet_grid(.~supp) +
    labs(x="Dose") +
    labs(y="Tooth Length") +
    labs(title="Tooth Length by Dose and Supplement")
```



```
ggplot(tgmean, aes(x=dose, y=len, group=supp)) +
    geom_line(aes(linetype=supp))+
    geom_point() +
    labs(x="Dose") +
    labs(y="Tooth Length") +
    labs(title="Average Tooth Length by Dose and Supplement")
```



Plot Conclusions

After reviewing both plots, it appears orange juice (OJ) is more effective than vitamin C (VC) at lower doses, however as we reach maximum dose (2ml) then both methods are equally effective. The following section puts that to the test, to see if (statistically speaking) the methods are similar or in fact different.

Confidence Intervals and Hypothesis Testing

Using confidence intervals and hypothesis t-tests (since our sample size is small) we'll see whether there is a statistically meaningful difference between the doses. We'll establish 4 hypothesis to test, then determine whether we reject or fail to reject each based on the test output with conclusions to support why for each.

We have a couple standard assumption across all our tests:

1. We'll use the 95% confidence interval to decide whether we reject or fail to reject.
2. The 10 pigs tested are not paired. In other words, the same 10 pigs were not used for each test variation.

Effect of tooth growth on two supplements (OJ and VC)

In this experiment, we hypothesize there is no effect on the average tooth growth based on the supplemental given (OJ or VC) regardless of dose. Let's put it to the test:

```
t.test(len ~ I(supp), paired=FALSE, data=tg)
```

```
##
##  Welch Two Sample t-test
##
## data:  len by I(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
```

There are a couple ways to look at this, all of which point towards failing to reject the null hypothesis. This concludes that dosage does play a role.

1. Our p-value (6%) is greater than 5%, so we fail to reject.
2. Our confidence interval, -0.17 to 7.57 contains 0, so we fail to reject.

Effect of tooth growth on low doses (<2ml) for different supplements

In this experiment, we hypothesize there is no effect on the average tooth growth between supplements administered at lower doses (<2ml).

Since doses are at 0.5, 1.0 and 2.0ml, we restrict the data set only to lower doses (<2ml) for this test.

```
t.test(len ~ I(supp), paired=FALSE, data=tg[tg$dose %in% c("0.5","1"),])
```

```
##
##  Welch Two Sample t-test
##
## data:  len by I(supp)
## t = 3.0503, df = 36.553, p-value = 0.004239
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  1.875234 9.304766
## sample estimates:
## mean in group OJ mean in group VC
##           17.965           12.375
```

Using similar criteria as the last test to judge our outcome, we find both offer supporting evidence to reject the null hypothesis, concluding that at low doses Orange Juice offers more "bang for the buck".

1. Our p-value (0.4%) is significantly smaller than 5%.
2. Our confidence interval does not contain 0, which means we have 95% confidence that we'll see an 1.88 to 9.30 lift in tooth growth in higher doses than lower.

Effect of tooth growth on high doses (2ml) for different supplements

Contrary to the last experiment, we'll see how high doses between supplements provide a meaningful difference. Our hypothesis is there is no meaningful difference.

```
t.test(len ~ I(supp), paired=FALSE, data=tg[tg$dose == "2",])
```

```
##
##  Welch Two Sample t-test
##
## data:  len by I(supp)
## t = -0.0461, 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
```

Since our p-value (96%) is higher than 5% and our confidence interval contains 0, we fail to reject our null hypothesis. This means at higher doses, there is no difference in the effect of different supplements.

Effect on tooth growth from lower doses (<2ml) to high doses (2ml)

Since we found there is no difference between supplements at higher doses, we want to test whether higher doses in fact do have an impact. Our hypothesis is they do not.

To ready the test, we need to group the low and high doses.

```
tg$dosegroup <- "low"
tg[tg$dose == "2",]$dosegroup <- "high"

t.test(len ~ I(dosegroup), paired=FALSE, data=tg)
```

```
##
##  Welch Two Sample t-test
##
## data:  len by I(dosegroup)
## t = 8.3085, df = 56.202, p-value = 2.347e-11
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##   8.294892 13.565108
## sample estimates:
## mean in group high  mean in group low
##              26.10              15.17
```

With a p-value less than 5% and a confidence interval that does not contain 0, we reject our null hypothesis and conclude that higher doses do in fact have significant effect over lower doses.

Hypothesis Testing Conclusions

Through these tests, we've found that higher doses of either Orange Juice or Vitamin C will offer significantly more tooth growth over low doses of either supplement. However, if you're constrained to lower doses, Orange Juice offers more "bang for the buck" than Vitamin C.