IS CODED PROJECT BUISNESS REPORT

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Problem Definition

Context:

A physiotherapist with a male football team is interested in studying the relationship between foot injuries and the positions at which the players play from the data collected.

Objective:

The primary objective is to analyze the relationship between foot injuries and player positions within the male football team to improve player performance, reduce injury-related costs, and enhance overall team success.

1. What is the probability that a randomly chosen player would suffer an injury?

2. What is the probability that a player is a forward or a winger?

3. What is the probability that a randomly chosen player plays in a striker position and has a foot injury?

4. What is the probability that a randomly chosen injured player is a striker?

Data Description

	Strike r	Forward	Attacking Midfielder	Winger	**Total**
Players Injured	45	56	24	20	**145**
Players Not Injured	32	38	11	9	**90**
Total	**77**	**94**	**35**	**29**	**235**

Table 1: Data Of Injured Players And Playing Position

```
Index: 3 entries, Players Injured to Total
Data columns (total 5 columns):
 #   Column                Non-Null Count  Dtype
---  ------                --------------  -----
 0   Striker               3 non-null      int64
 1   Forward               3 non-null      int64
 2   Attacking Midfielder  3 non-null      int64
 3   Winger                3 non-null      int64
 4   Total                 3 non-null      int64
dtypes: int64(5)
```

Table 2: Basic Information Of Dataset(Injured Players)

There are 3 rows(Injured, non injured and their total count) and 5 features(different playing positions Striker, Forward, Attacking Midfielder and winger along with the total count). All the data values are in correct format and also all the Totals are adding up.

Statistical Summary

Position	Striker	Forward	Attacking Midfielder	Winger	Total
count	3.000000	3.000000	3.000000	3.000000	3.000000
mean	51.333333	62.666667	23.333333	19.333333	156.666667
std	23.158872	28.589042	12.013881	10.016653	73.200638
min	32.000000	38.000000	11.000000	9.000000	90.000000
25%	38.500000	47.000000	17.500000	14.500000	117.500000
50%	45.000000	56.000000	24.000000	20.000000	145.000000
75%	61.000000	75.000000	29.500000	24.500000	190.000000
max	77.000000	94.000000	35.000000	29.000000	235.000000

Table 3: Numerical summarization of the dataset(Injured Players)

Answer Key Questions

- ***What is the probability that a randomly chosen player would suffer an injury?***

Total injured players = 145

Total players = 235

Probability of injury = total injured players / total players

Probability of injury = 145/235 = 0.617

probability that a randomly chosen player would suffer an injury is : 0.617.

There is a 61.7%(approx 62%) that a randomly chosen player would suffer an injury.

- ***What is the probability that a player is a forward or a winger?***

Total forward player =94

Total wingers =29

Total players=235

Probability=(total forward player+total wingers)/total players

Probability=(94+29)/235 = 0.523.

Probability that a player is a forward or a winger : 0.523
There is a 52.3%(approx 52%) that a player would be either a forward or a winger.

- ***What is the probability that a randomly chosen player plays in a striker position and has a foot injury?***

Striker injured=45

Total players=235

Probability= Striker injured/Total players

Probability=45/235 = 0.191

Probability that a randomly chosen player plays in a striker position and has a foot injury : 0.191

There is a 19.1%(approx 19%) that a randomly chosen player plays in a striker position and has a foot injury.

- ***What is the probability that a randomly chosen injured player is a striker?***

Striker injured=45
Total injured players=145

Probability = striker injured/total injured players

Probability = 45/145 = 0.31

Probability that a randomly chosen injured player is a striker : 0.31.

There is a 31% that a randomly chosen injured player is a striker.

Problem 2

Problem Definition

Context:

The breaking strength of gunny bags used for packaging cement is normally distributed with a mean of 5 kg per sq. centimeter and a standard deviation of 1.5 kg per sq. centimeter. The quality team of the cement company wants to know the following about the packaging material to better understand wastage or pilferage within the supply chain.

Objective:

The quality team of the cement company wants to know the following about the packaging material to better understand wastage or pilferage within the supply chain:

1 What proportion of the gunny bags have a breaking strength of less than 3.17 kg per sq cm?

2 What proportion of the gunny bags have a breaking strength of at least 3.6 kg per sq cm.?

3 What proportion of the gunny bags have a breaking strength between 5 and 5.5 kg per sq cm.?

4 What proportion of the gunny bags have a breaking strength NOT between 3 and 7.5 kg per sq cm.?

Visual Representation :

Mean=5 kg per sq.

Standard Deviation=1.5 kg per sq. cm.

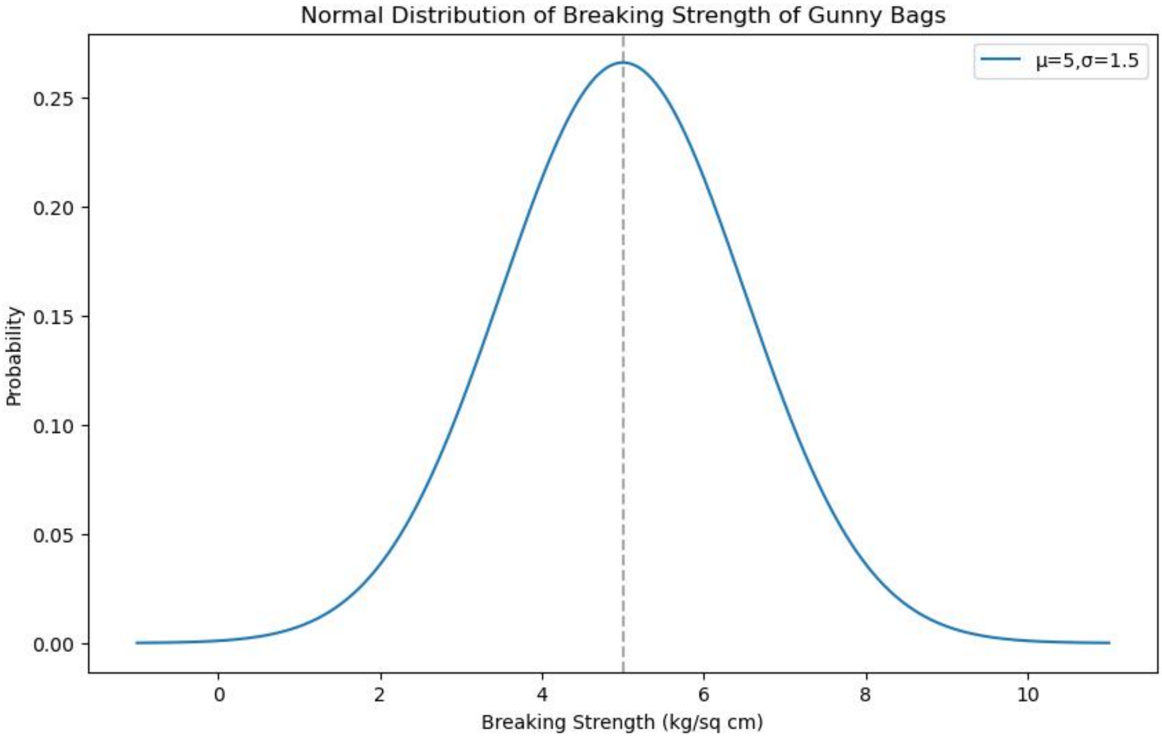

Figure 1:Normal Distribution of Breaking Strength of Gunny Bags

Answer Key Questions :

- ***What proportion of the gunny bags have a breaking strength of less than 3.17 kg per sq cm?***

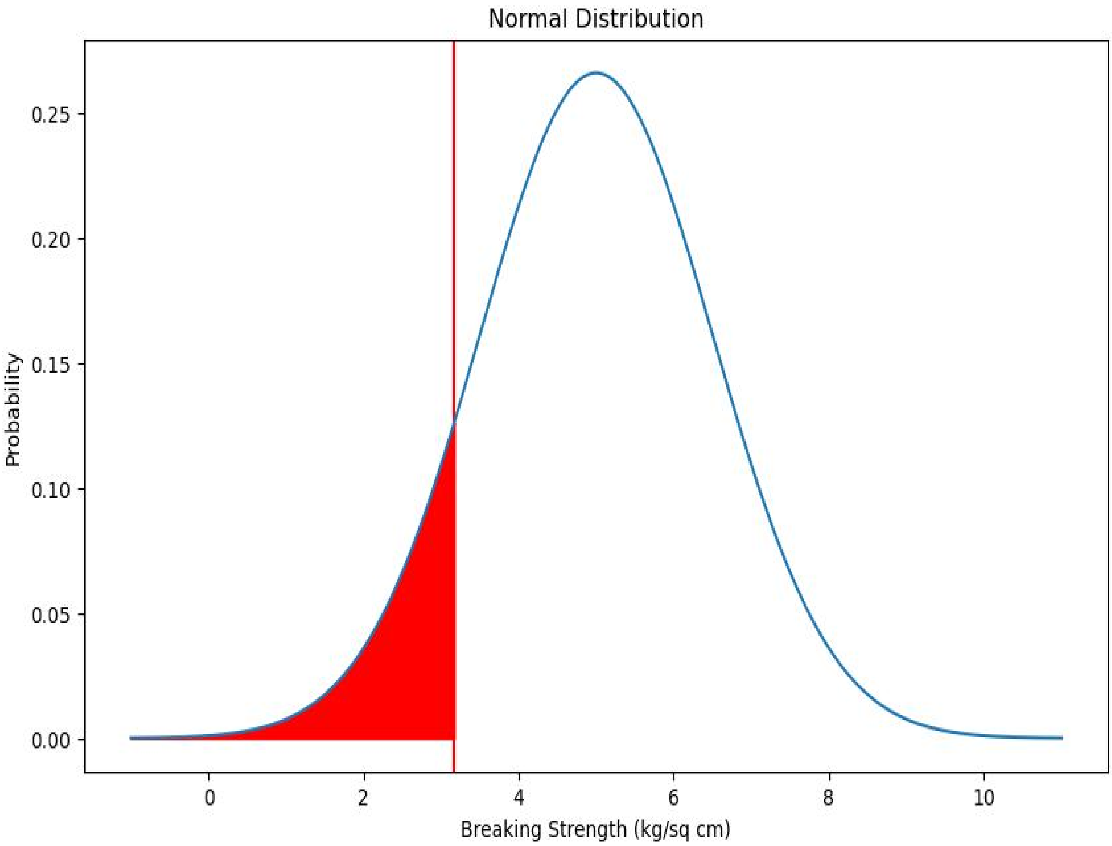

Figure 2:Normal Distribution for breaking strength of less than 3.17 kg per sq. cm.

The red marked area represents the area under Normal distribution where breaking strength is less than 3.17 kg per sq cm (Above 3.17 kg per sq cm).

Proportion of gunny bags with breaking strength less than 3.17 kg/sq.cm: 0.111.

Approximately 11.12% of the gunny bags have a breaking strength below 3.17 kg/sq.cm.

- ***What proportion of the gunny bags have a breaking strength of at least 3.6 kg per sq cm.?***

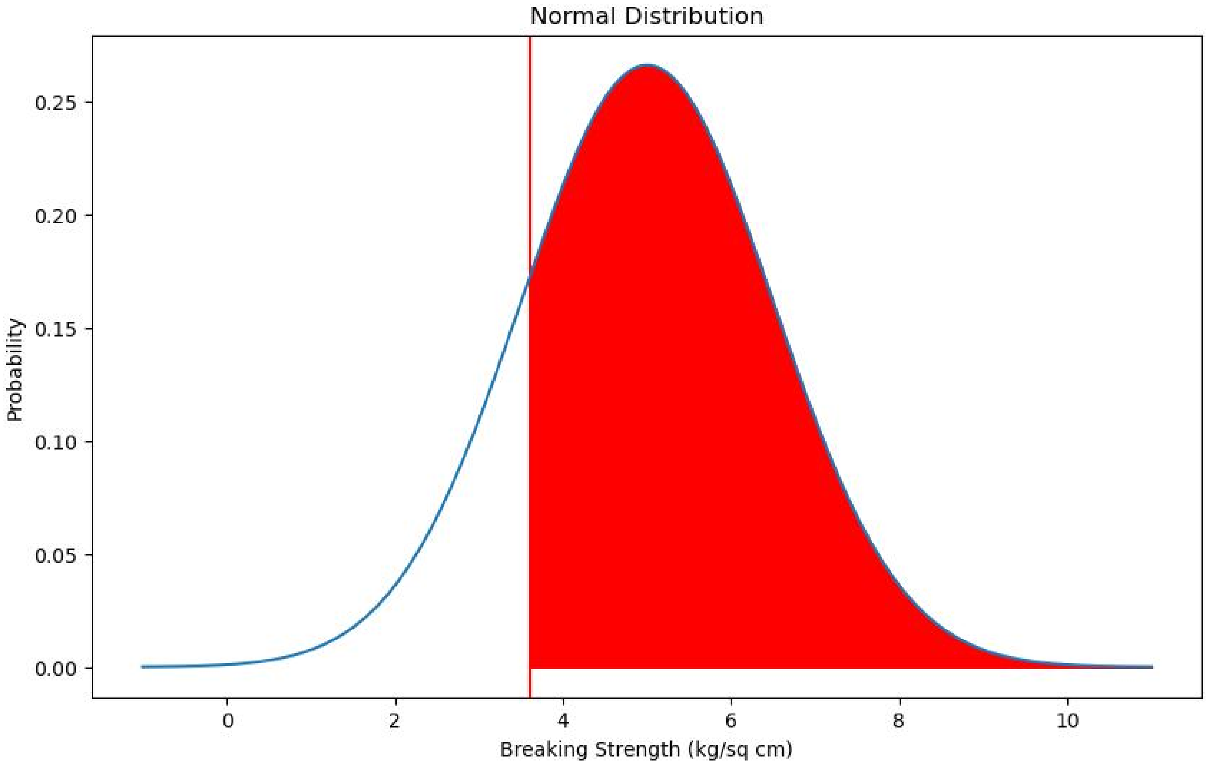

Figure 3:Normal Distribution for breaking strength at least 3.6 kg per sq cm.

The red marked area represents the area under Normal distribution where breaking strength is at least 3.6 kg per sq cm (Above 3.6 kg per sq cm).

Proportion of of the gunny bags have a breaking strength of at least 3.6 kg per sq cm.: 0.825.

Approximately 82.5% of the gunny bags have a breaking strength of at least 3.6 kg per sq cm.

- ***What proportion of the gunny bags have a breaking strength between 5 and 5.5 kg per sq cm.?***

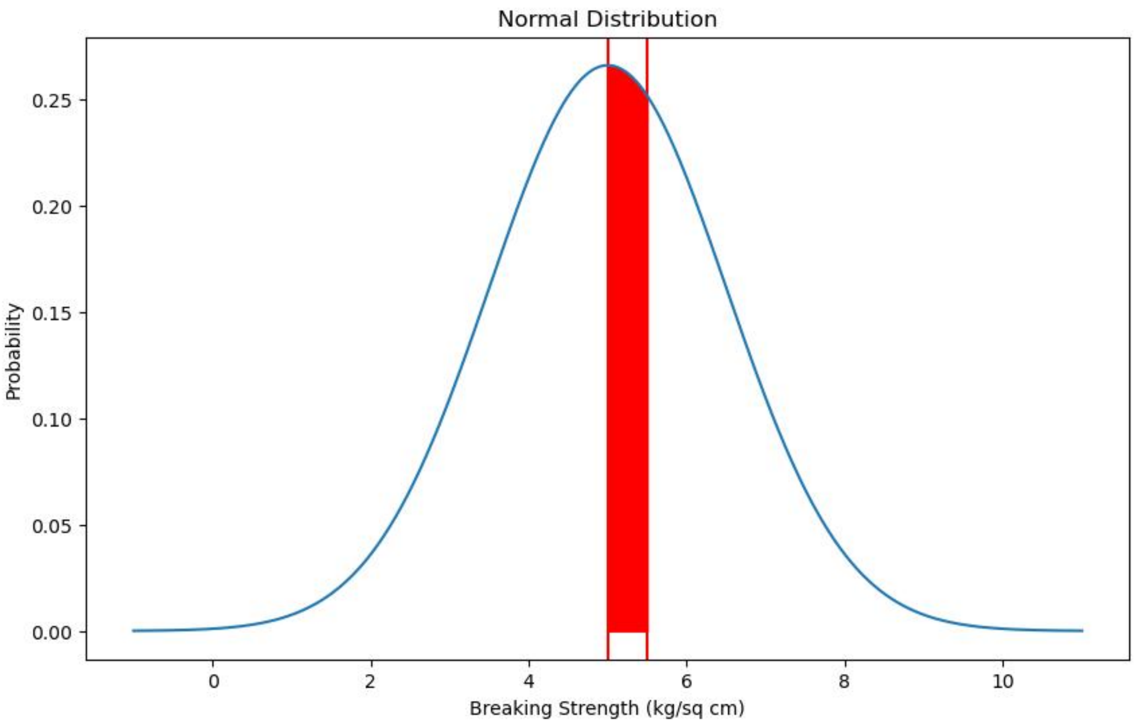

Figure 4:Normal Distribution for breaking strength between 5 and 5.5 kg per sq cm.

The red marked area represents the area under Normal distribution where breaking strength is between 5 and 5.5 kg per sq cm.

Proportion of the gunny bags having a breaking strength between 5 and 5.5 kg per sq cm. : 0.131

Approximately 13.1% of the gunny bags have a breaking strength between 5 and 5.5 kg per sq cm.

- ***What proportion of the gunny bags have a breaking strength NOT between 3 and 7.5 kg per sq cm.?***

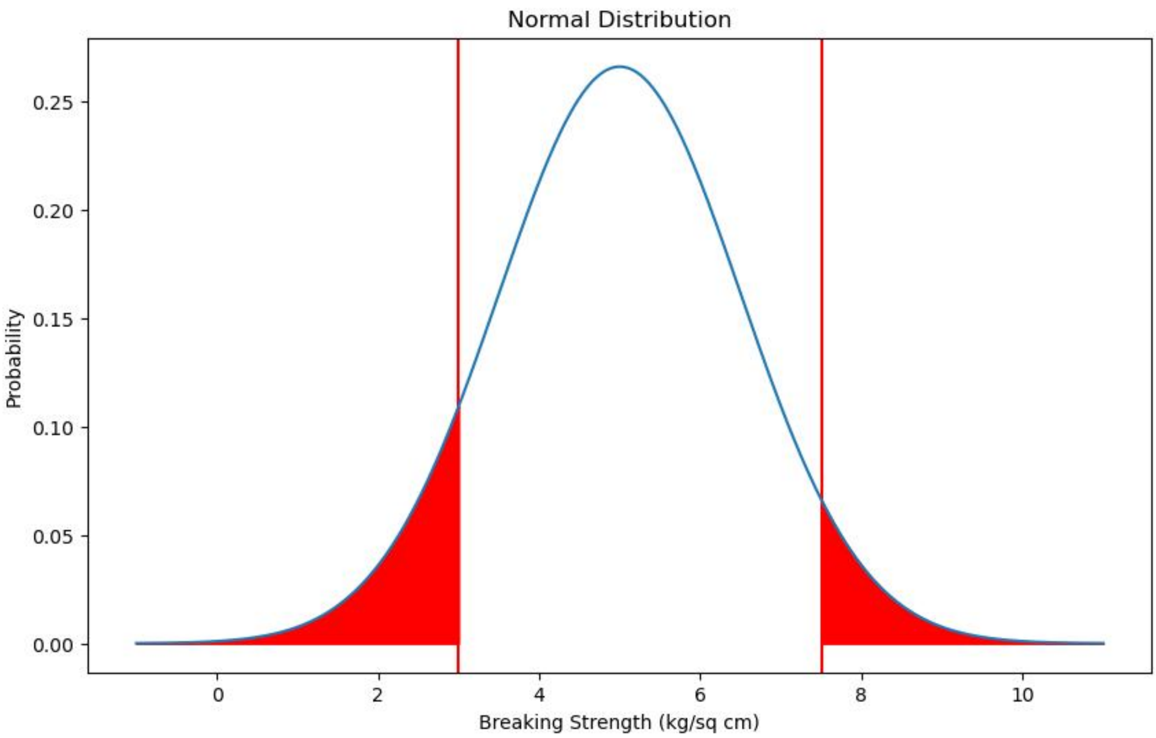

Figure 5:Normal Distribution for Breaking strength NOT between 3 and 7.5 kg per sq cm.

The red marked area represents the area under Normal distribution where breaking strength is not between 3 and 7.5 kg per sq cm. (below 3 and above 7.5 kg per sq cm.).

Proportion of the gunny bags have a breaking strength NOT between 3 and 7.5 kg per sq cm. : 0.139.

Approximately 13.9% of the gunny bags have a breaking strength NOT between 3 and 7.5 kg per sq cm.

Problem 3

Problem Definition

Context:

Zingaro stone printing is a company that specializes in printing images or patterns on polished or unpolished stones. However, for the optimum level of printing of the image, the stone surface has to have a Brinell's hardness index of at least 150. Recently, Zingaro has received a batch of polished and unpolished stones from its clients.

Objective:

Zingaro has received a batch of polished and unpolished stones from its clients. Use the data provided to answer the following (assuming a 5% significance level).

1. Zingaro has reason to believe that the unpolished stones may not be suitable for printing. Do you think Zingaro is justified in thinking so?

2. Is the mean hardness of the polished and unpolished stones the same?

Data Description

Zingaro_Company.csv : The data set contains Brinell's hardness index of Unpolished stones and Treated and Polished stones.

Data Overview:

Load the required packages, set the working directory, and load the data file.

The dataset has 75 rows and 2 columns. It is always a good practice to view a sample of the rows. A simple way to do that is to use head() function.

	Unpolished	Treated and Polished
0	164.481713	133.209393
1	154.307045	138.482771
2	129.861048	159.665201
3	159.096184	145.663528
4	135.256748	136.789227

Table 4: Top five rows of dataset(Brinell's hardness index)

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 75 entries, 0 to 74
Data columns (total 2 columns):
 #   Column                Non-Null Count  Dtype  
---  ------                --------------  -----  
 0   Unpolished            75 non-null     float64
 1   Treated and Polished  75 non-null     float64
dtypes: float64(2)
memory usage: 1.3 KB
```

Table 5: Basic information of dataset(Brinell's hardness index)

Visualization and Outliers:

Histogram:

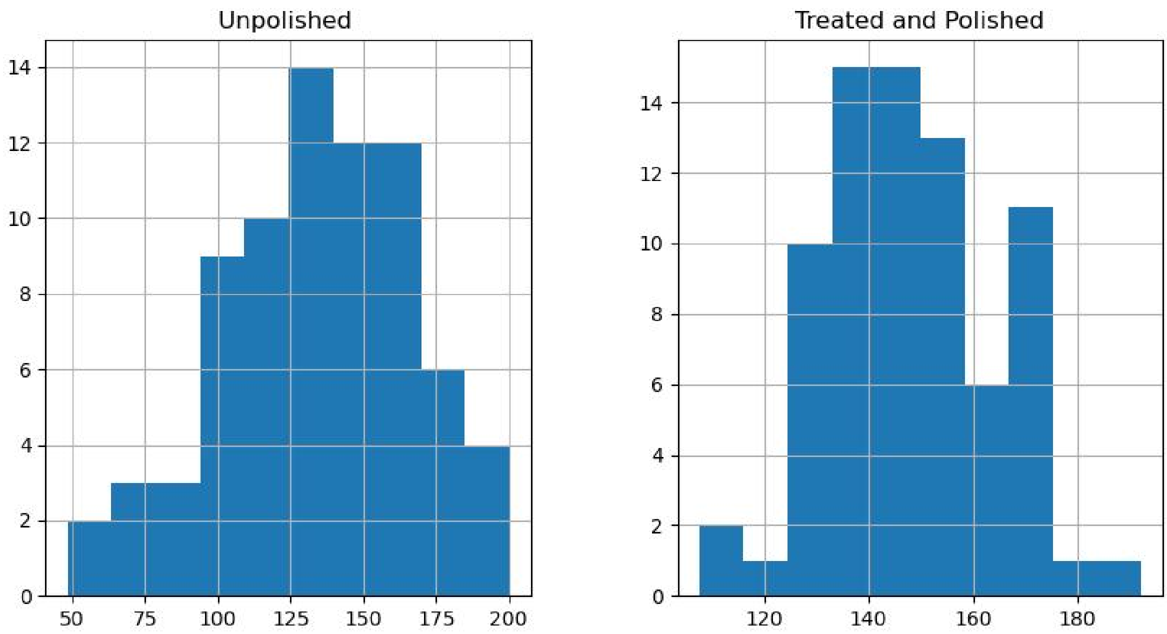

Figure 6:Distribution of Brinell Hardness by Stone Type.

Box plot:

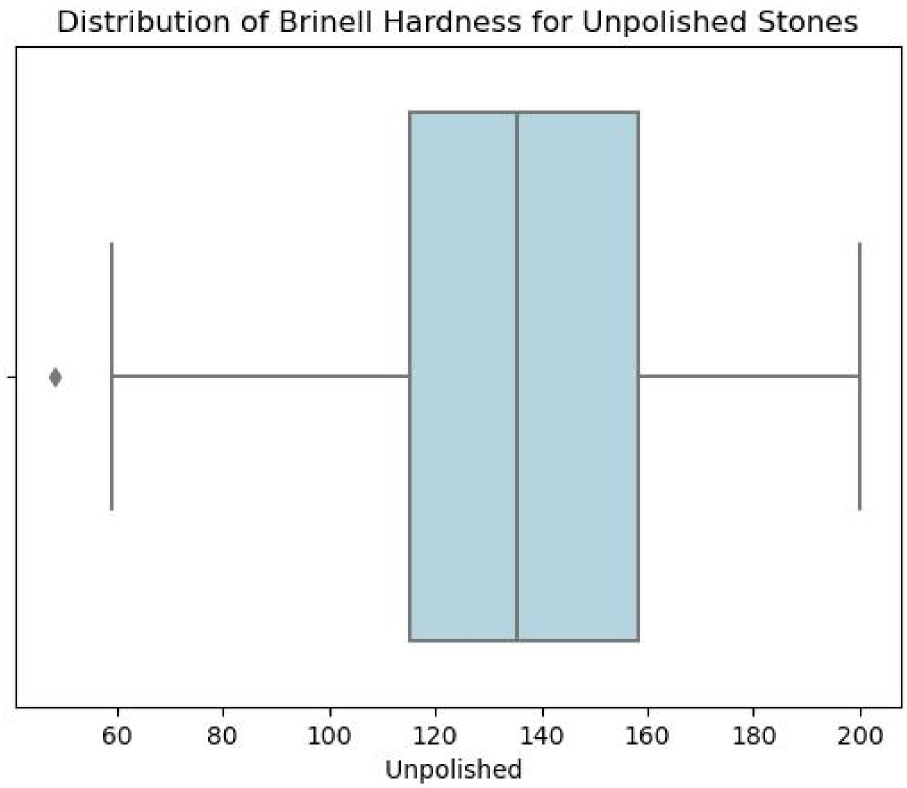

Figure 7:Distribution of Brinell Hardness for Unpolished Stones.

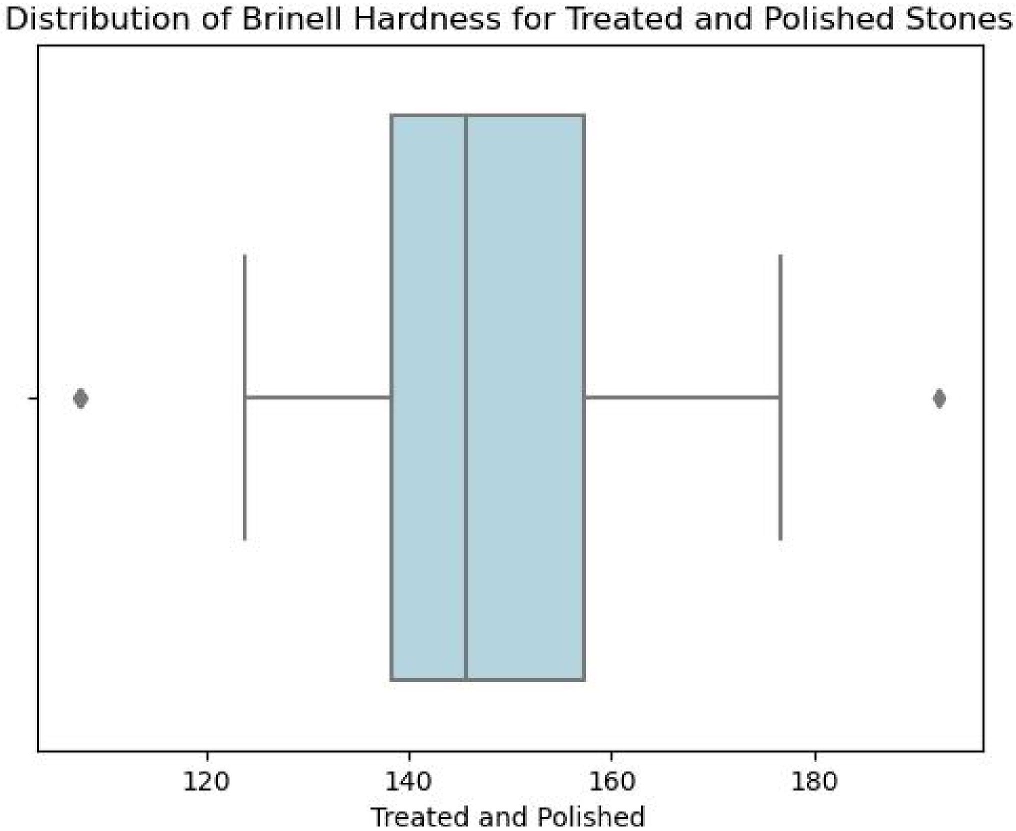

Figure 8:Distribution of Brinell Hardness (Treated and Polished Stones)

We found outliers and we treated them using IQR method.

Answer Key Questions

- ***Zingaro has reason to believe that the unpolished stones may not be suitable for printing. Do you think Zingaro is justified in thinking so?***

To determine if Zingaro is justified in thinking that the unpolished stones may not be suitable for printing, we can perform a hypothesis test.

In one sample test, we compare the population parameter such as mean of a single sample of data collected from a single population.

Population Mean = 150.

Step 1: Define null and alternative hypotheses

Null Hypothesis (H0): The mean hardness of the unpolished stones is at least 150.

H0: mean(μ)>=150.

Alternate Hypothesis (H1): The mean hardness of the unpolished stones is less than 150.

H1: mean(μ)<150.

Step 2 : Decide the significance level

level of significance **α = 0.05**.

Step 3 : Identify the test statistic:

We do not know the population standard deviation. So we use the t distribution and the T_stat test statistic.

Step 4 : Calculate the p - value and test statistic:

'scipy.stats.ttest_1samp' calculates the t test for the mean of one sample given the sample observations and the expected value in the null hypothesis. This function returns t statistic and the two-tailed p value.

One sample t test
t statistic: -4.166875533846615
p value: 8.276372710325264e-05

Step 5 : Decide to reject or accept null hypothesis:

Level of significance: 0.05

We have evidence to reject the null hypothesis since p value < Level of significance

Our one-sample t-test p-value= 8.276372710325264e-05

Conclusion *:*

As p-value is lesser than α(0.05) reject the null hypothesis:

There is significant evidence at the 5% significance level to conclude that the mean hardness of the unpolished stones is less than 150.

This is enough proof to think Zingaro is justified in thinking that the unpolished stones may not be suitable for printing.

- ***Is the mean hardness of the polished and unpolished stones the same?***

We can use a two sample T-test for this question as the standard deviation of the population is unknown.

Step 1: Define null and alternative hypotheses:

Null Hypothesis (H0): The mean hardness of the polished stones is equal to the mean hardness of the unpolished stones.

H0: $\mu1 = \mu2$

Alternate Hypothesis (H1): The mean hardness of the polished stones is different from the mean hardness of the unpolished stones.

H1: $\mu1 \neq \mu2$

Step 2 : Decide the significance level **:**

level of significance **$\alpha = 0.05$**.

Step 3 : Identify the test statistic :

We do not know the population standard deviation and sample size is the same. So we use the t distribution and the t_STAT test statistic.

Step 4 :Calculate the p - value and test statistic :

We use the *scipy.stats.ttest_ind* to calculate the t-test for the means of **TWO INDEPENDENT** samples of scores given the two sample observations. This function returns t statistic and two-tailed p value.

tstat -3.2412275512430875
P Value 0.0014703419909888047

Step 5 : Decide to reject or accept null hypothesis:

two-sample t-test p-value= 0.0014703419909888047

Reject the null hypothesis: The mean hardness of polished and unpolished stones is significantly different.

Conclusion ***:***

As p_value is lesser than α(0.05) reject the null hypothesis:

We conclude that the mean hardness of the polished and unpolished stones are different, μ_A is not equal to μ_B.

Problem 4

Problem Definition

Context:

In a dental clinic or laboratory setting, understanding the factors influencing the hardness of dental implants is crucial for ensuring patient satisfaction and successful implantation procedures.

The hardness of metal implants in dental cavities depends on multiple factors, such as the method of implant, the temperature at which the metal is treated, the alloy used as well as the dentists who may favor one method above another and may work better in his/her favorite method. The response is the variable of interest.

Objective:

Find answers to the following questions:

1. How does the hardness of implants vary depending on dentists?

2. How does the hardness of implants vary depending on methods?

3. What is the interaction effect between the dentist and method on the hardness of dental implants for each type of alloy?

4. How does the hardness of implants vary depending on dentists and methods together?

Data Description

Dental+Hardness+data.xlsx : Contains 4 sheets under which necessary data is provided under sheet named “Data”. It has data for 5 kind of

Doctors, 3 types of Methods and 2 types of Alloy along with their Response(Hardness).

Top 5 rows of data:

	Dentist	Method	Alloy	Temp	Response
0	1	1	1	1500	813
1	1	1	1	1600	792
2	1	1	1	1700	792
3	1	1	2	1500	907
4	1	1	2	1600	792

Table 6: Top five rows of dataset(Dental Hardness)

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 90 entries, 0 to 89
Data columns (total 5 columns):
 #   Column    Non-Null Count  Dtype
---  ------    --------------  -----
 0   Dentist   90 non-null     int64
 1   Method    90 non-null     int64
 2   Alloy     90 non-null     int64
 3   Temp      90 non-null     int64
 4   Response  90 non-null     int64
dtypes: int64(5)
memory usage: 3.6 KB
```

Table 7: Basic information of dataset(Dental Hardness)

We can see that for Dentist, Method, Alloy and Temp the data type is shown as int, which is incorrect as it should be categorical values. We need to convert them into categorical values.

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 90 entries, 0 to 89
Data columns (total 5 columns):
 #   Column    Non-Null Count  Dtype
---  ------    --------------  -----
 0   Dentist   90 non-null     category
 1   Method    90 non-null     category
 2   Alloy     90 non-null     category
 3   Temp      90 non-null     category
 4   Response  90 non-null     int64
dtypes: category(4), int64(1)
memory usage: 1.8 KB
```

Table 8: Basic information of dataset after conversion(Dental Hardness)

	Dentist	Method	Alloy	Temp
count	90	90	90	90
unique	5	3	2	3
top	1	1	1	1500
freq	18	30	45	30

Table 9: Categorical Values(Dental Hardness)

We didn’t find any missing values, so we are moving forward to Key questions.

Answer Key Questions

To analyze how the hardness of dental implants varies based on the factors mentioned (dentists, methods, and alloys), you can use a statistical approach of ANOVA (Analysis of Variance).

As both types of alloys cannot be considered together. We must conduct the analysis separately for the two types of alloys:

df_alloy1 where alloy = 1

	Dentist	Method	Alloy	Temp	Response
0	1	1	1	1500	813
1	1	1	1	1600	792
2	1	1	1	1700	792
6	1	2	1	1500	782
7	1	2	1	1600	698

Table 10: Top five rows of df_alloy1 (Dental Hardness)

df_alloy2 where alloy = 2

	Dentist	Method	Alloy	Temp	Response
3	1	1	2	1500	907
4	1	1	2	1600	792
5	1	1	2	1700	835
9	1	2	2	1500	1115
10	1	2	2	1600	835

Table 11: Top five rows of df_alloy2 (Dental Hardness)

- ***How does the hardness of implants vary depending on dentists?***

Step 1: Define Null and Alternate Hypothesis***:***

Null Hypothesis (H0): The hardness of implants does not vary depending on dentists (mean hardness is the same for all dentists).

Alternate Hypothesis (H1): The hardness of implants varies depending on dentists (mean hardness is not the same for all dentists)

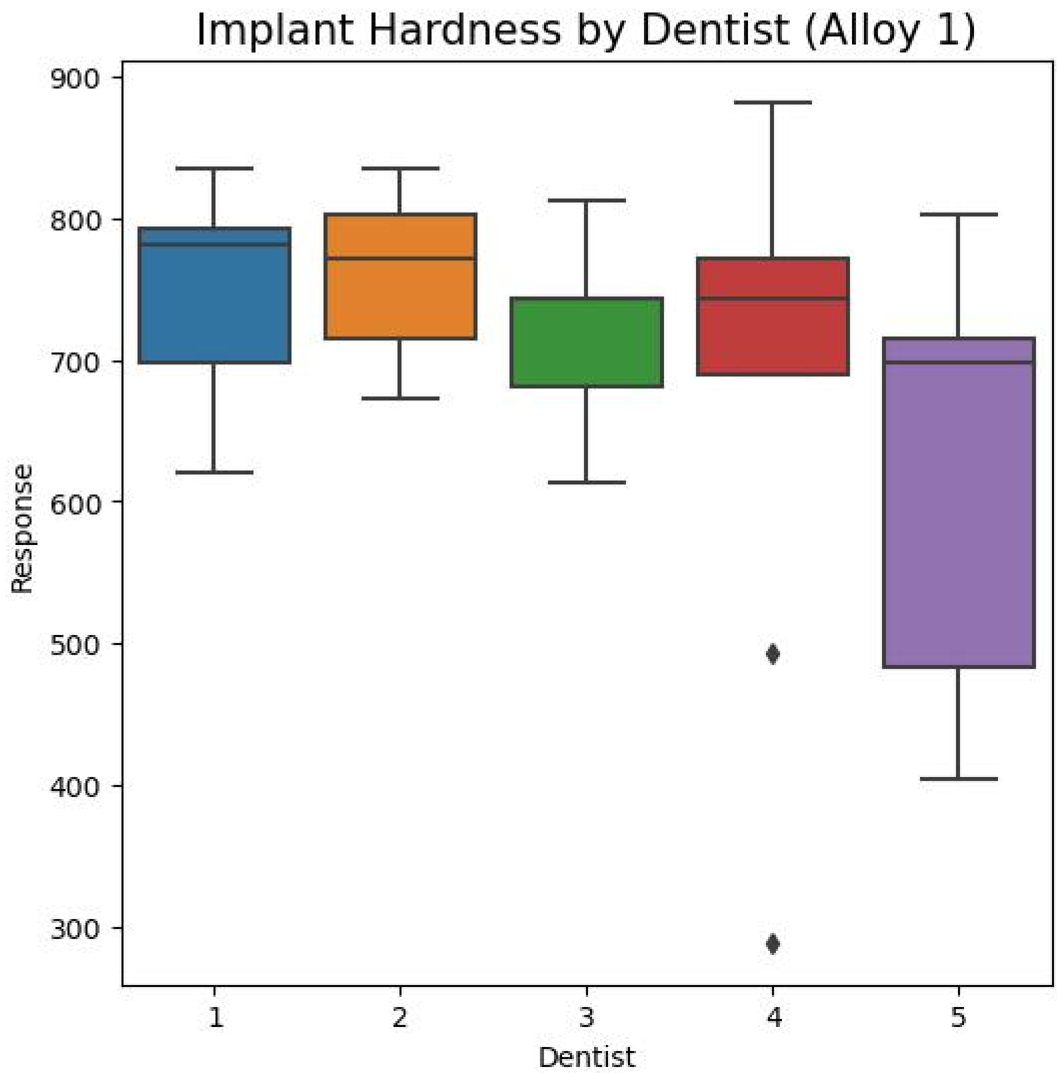

Figure 9:Implant Hardness by Dentist (Alloy 1)

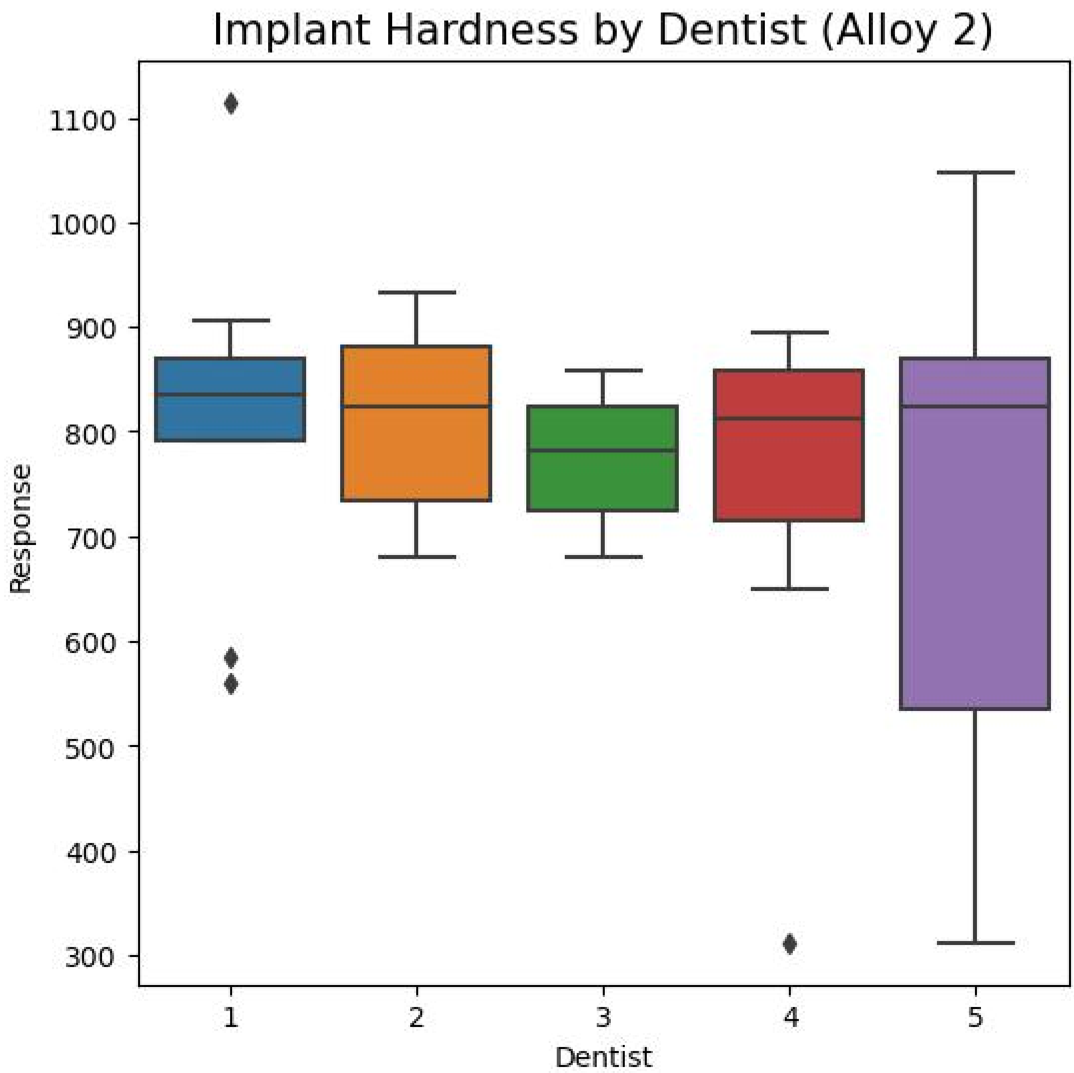

Figure 10:Implant Hardness by Dentist (Alloy 2)

Step 2: Identify the test statistic :

In this analysis, we aim to determine if there are significant differences in the mean implant hardness among dentists. We will utilize a One-way ANOVA test to compare the means from multiple dentists and assess if there is any significant variation in implant hardness attributed to different dentists. However, to ensure the reliability of the ANOVA results, we need to verify two key assumptions:

One-way ANOVA test

1.Normality Assumption: Shapiro-Wilk’s test will be applied to the response variable (implant hardness) to assess if the data follows a normal distribution.

3. Equality of Variance Assumption: Levene's test will be applied to the response variable to assess if the variance of implant hardness is equal across all dentists.

Step 3: Deciding the Level of significance :

level of significance **α = 0.05**.

Step 4: Shapiro-Wilk’s test :

Null hypothesis and Alternative hypothesis for Shapiro Wilk’s test:

H0: Distribution of implant hardness measurements follows a normal distribution .

H1: Distribution of implant hardness measurements deviates from a normal distribution.

By using the function ‘*stats.shapiro*’ we found:

Shapiro-Wilk's test p-value for Alloy 1: 1.1945070582441986e-05
Shapiro-Wilk's test p-value for Alloy 2: 0.00040293222991749644

Since p-value(both alloy type 1 and 2) of the test is smaller than the 5% significance level, we can reject the null hypothesis that the response follows the normal distribution.

Step 4: Levene’s test :

Null Hypothesis and Alternate Hypothesis:

H0: All the population variances are equal.
H1: At least one variance is different from the rest.

By using ‘*stats.levene*’ function we found:

Levene's test p-value for Alloy 1: 0.2565537418543795
Levene's test p-value for Alloy 2: 0.23686777576324952

Since the p-value(for both alloys) is large than the 5% significance level, we fail to reject the null hypothesis of homogeneity of variances.

Step 5: Calculate the p-value:

We will use the f_oneway() function from the scipy.stats library to perform a one-way ANOVA test.

The f_oneway() function takes the sample observations from the different groups and returns the test statistic and the p-value for the test.

The sample observations are the implant hardness measurements with respect to the Dentists.

ANOVA p-value for Alloy 1: 0.8028113128531966
ANOVA p-value for Alloy 2: 0.7180309510793431

Step 6: Compare the p-value with **α** :

As P- value is greater than 0.05(**α - Level of significance):**

Fail to reject null hypothesis: There are no significant differences in implant hardness among dentists for Alloy 1.

Fail to reject null hypothesis: There are no significant differences in implant hardness among dentists for Alloy 1.

Step 7: Multiple Comparison test (Tukey HSD) :

Even though null hypothesis is not rejected, we are conducting Tukey's HSD test.

Multiple Comparison of Means - Tukey HSD, FWER=0.05

group1	group2	meandiff	p-adj	lower	upper	reject
1	2	11.3333	0.9996	-145.0423	167.709	False
1	3	-32.3333	0.9757	-188.709	124.0423	False
1	4	-68.7778	0.7189	-225.1535	87.5979	False
1	5	-122.2222	0.1889	-278.5979	34.1535	False
2	3	-43.6667	0.9298	-200.0423	112.709	False
2	4	-80.1111	0.5916	-236.4868	76.2646	False
2	5	-133.5556	0.1258	-289.9312	22.8201	False
3	4	-36.4444	0.9626	-192.8201	119.9312	False
3	5	-89.8889	0.4805	-246.2646	66.4868	False
4	5	-53.4444	0.8643	-209.8201	102.9312	False

Table 12: Multiple Comparison test of Alloy1 (Dentists)

Table 10: Top five rows of df_alloy2 (Dental Hardness)

Multiple Comparison of Means - Tukey HSD, FWER=0.05

group1	group2	meandiff	p-adj	lower	upper	reject
1	2	-4.1111	1.0	-225.5687	217.3465	False
1	3	-36.5556	0.9895	-258.0131	184.902	False
1	4	-70.0	0.8941	-291.4576	151.4576	False
1	5	-90.1111	0.7724	-311.5687	131.3465	False
2	3	-32.4444	0.9933	-253.902	189.0131	False
2	4	-65.8889	0.9132	-287.3465	155.5687	False
2	5	-86.0	0.8008	-307.4576	135.4576	False
3	4	-33.4444	0.9925	-254.902	188.0131	False
3	5	-53.5556	0.9574	-275.0131	167.902	False
4	5	-20.1111	0.999	-241.5687	201.3465	False

Table 13: Multiple Comparison test of Alloy2 (Dentists)

Conclusion:

1. Shapiro-Wilk's test indicates that the normality assumption is violated for dentists for both Alloy type 1 and type 2.

2. For both Alloy 1 and Alloy 2, there are no significant differences in implant hardness among dentists.

3. The variations in implant hardness observed cannot be attributed to differences in dentists but may be influenced by other factors such as the method of implant, temperature.

4. ANOVA p-value is greater than the significance level (0.05), indicating no significant difference in implant hardness among dentists for Alloy 1 and Alloy 2.

- ***How does the hardness of implants vary depending on methods?***

Step 1: Define Null and Alternate Hypothesis***:***

Null Hypothesis (H0): There is no significant difference in implant hardness across different methods.

Alternate Hypothesis (H1): There is a significant difference in implant hardness across different methods.

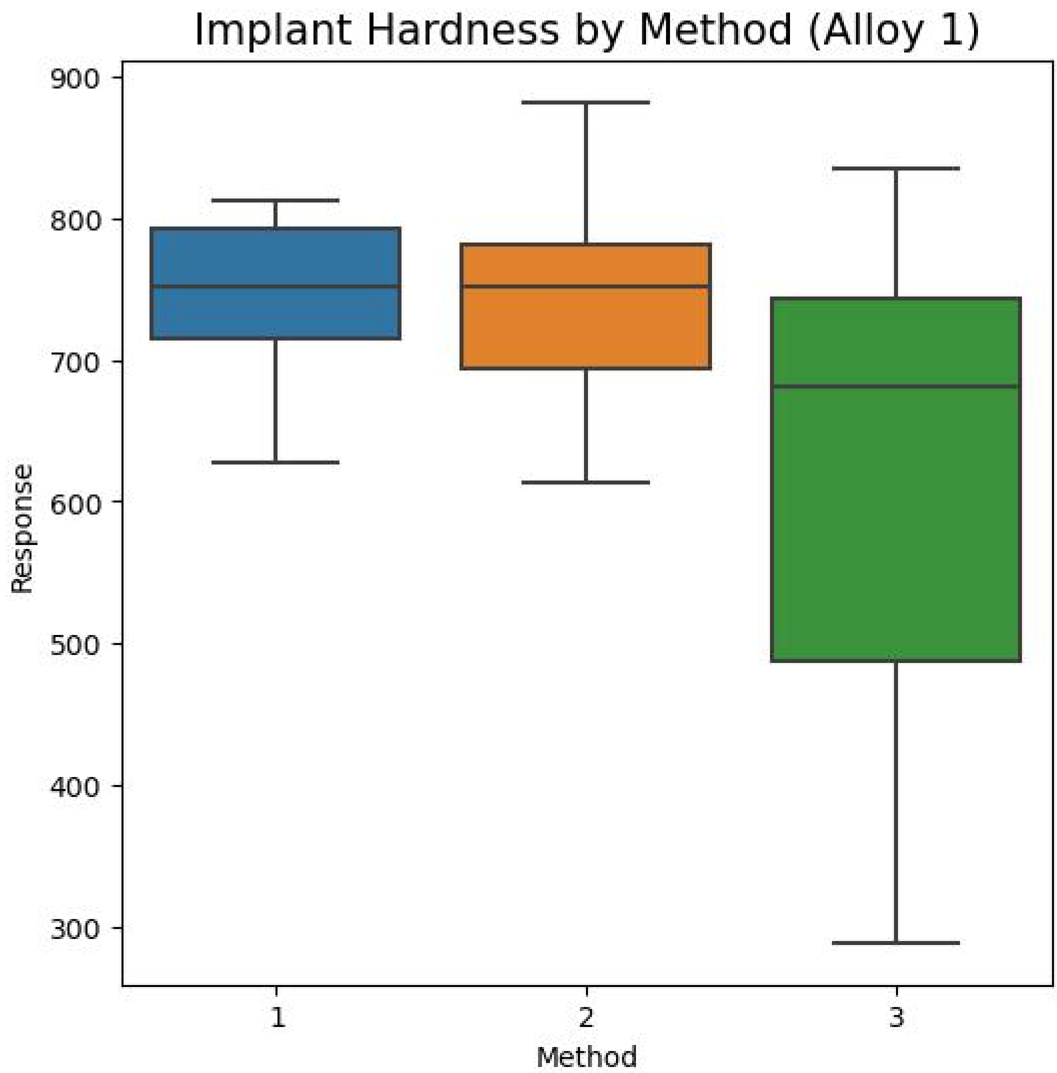

Figure 11:Implant Hardness by Method(Alloy 1)

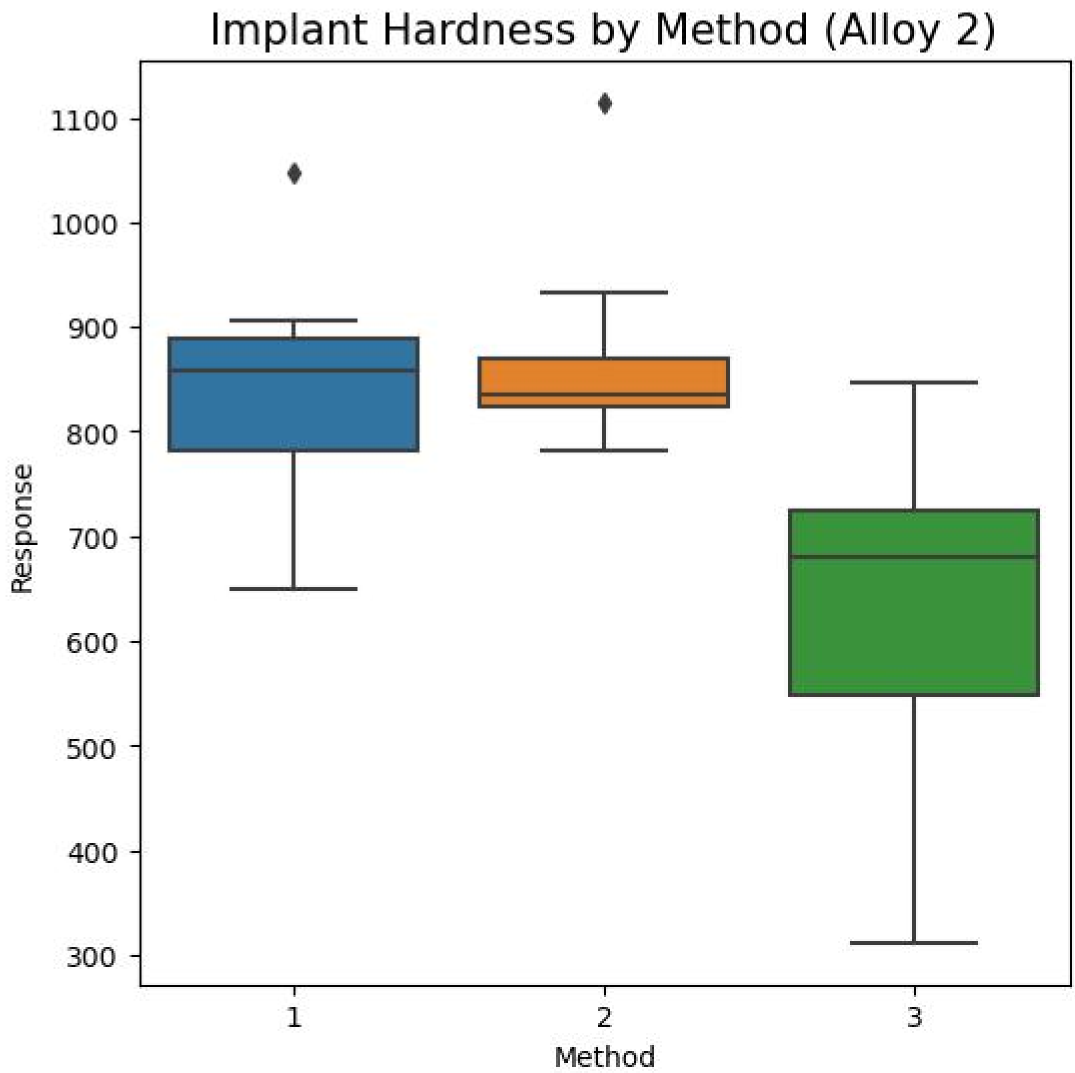

Figure 12:Implant Hardness by Method(Alloy 2)

Step 2: Identify the test statistic :

In this analysis, we aim to determine if there are significant differences in the mean implant hardness among methods. We will utilize a One-way ANOVA test to compare the means from multiple methods and assess if there is any significant variation in implant hardness attributed to different methods. However, to ensure the reliability of the ANOVA results, we need to verify two key assumptions:

One-way ANOVA test

1.Normality Assumption: Shapiro-Wilk's test will be applied to the response variable (implant hardness) to assess if the data follows a normal distribution.

2. Equality of Variance Assumption: Levene's test will be applied to the response variable to assess if the variance of implant hardness is equal across all methods.

Step 3: Deciding the Level of significance :

level of significance **α = 0.05**.

Step 4: Shapiro-Wilk's test :

Null hypothesis and Alternative hypothesis for Shapiro Wilk's test:

H0: Distribution of implant hardness measurements follows a normal distribution.

H1: Distribution of implant hardness measurements deviates from a normal distribution.

By using the function '*stats.shapiro*' we found:

Shapiro-Wilk's test p-value for Alloy 1: 1.1945070582441986e-05
Shapiro-Wilk's test p-value for Alloy 2: 0.00040293222991749644

Since p-value(both alloy type 1 and 2) of the test is smaller than the 5% significance level, we can reject the null hypothesis that the response follows the normal distribution.

Step 4: Levene's test :

Null Hypothesis and Alternate Hypothesis:

H0: All the population variances are equal.

H1: At least one variance is different from the rest.

By using '*stats.levene*' function we found:

Levene's test p-value for Alloy 1: 0.0034160381460233975
Levene's test p-value for Alloy 2: 0.04469269939158668

Since the p-value(for both alloys) is smaller than the 5% significance level, reject the null hypothesis of homogeneity of variances.

Step 5: Calculate the p-value:

We will use the f_oneway() function from the scipy.stats library to perform a one-way ANOVA test.

The f_oneway() function takes the sample observations from the different groups and returns the test statistic and the p-value for the test.

The sample observations are the implant hardness measurements with respect to the Methods.

ANOVA p-value for Alloy 1: 0.004163412167505543

ANOVA p-value for Alloy 2: 5.415871051443187e-06

Step 6: Compare the p-value with **α** :

As P- value is lesser than 0.05(**α - Level of significance):**

Reject null hypothesis: There are significant differences in implant hardness among dentists for Alloy 1.

Reject null hypothesis: There are significant differences in implant hardness among dentists for Alloy 1.

Step 7: Multiple Comparison test (Tukey HSD) :

Even though null hypothesis is not rejected, we are conducting Tukey's HSD test.

Multiple Comparison of Means - Tukey HSD, FWER=0.05

group1	group2	meandiff	p-adj	lower	upper	reject
1	2	-6.1333	0.987	-102.714	90.4473	False
1	3	-124.8	0.0085	-221.3807	-28.2193	True
2	3	-118.6667	0.0128	-215.2473	-22.086	True

Table 14: Multiple Comparison test of Alloy1 (Methods)

Multiple Comparison of Means - Tukey HSD, FWER=0.05

group1	group2	meandiff	p-adj	lower	upper	reject
1	2	27.0	0.8212	-82.4546	136.4546	False
1	3	-208.8	0.0001	-318.2546	-99.3454	True
2	3	-235.8	0.0	-345.2546	-126.3454	True

Table 15: Multiple Comparison test of Alloy2 (Methods)

Conclusion:

- Shapiro-Wilk's test indicates that the normality assumption is violated for dentists for both Alloy type 1 and type 2.
- Significant difference is observed between Method 1 and Method 3 and Method 2 and Method 3 for Alloy 1.
- Significant difference is observed between Method 1 and Method 3 and Method 2 and Method 3 for Alloy 2.
- ANOVA p-value is smaller than the significance level (0.05), indicating significant difference in implant hardness among Methods for Alloy 1 and Alloy 2.
- For both Alloy 1 and Alloy 2, Methods 1 and 3, as well as Methods 2 and 3, exhibit significant differences in implant hardness.
- No significant difference in implant hardness is found between Methods 1 and 2 for either alloy.

- ***What is the interaction effect between the dentist and method on the hardness of dental implants for each type of alloy?***

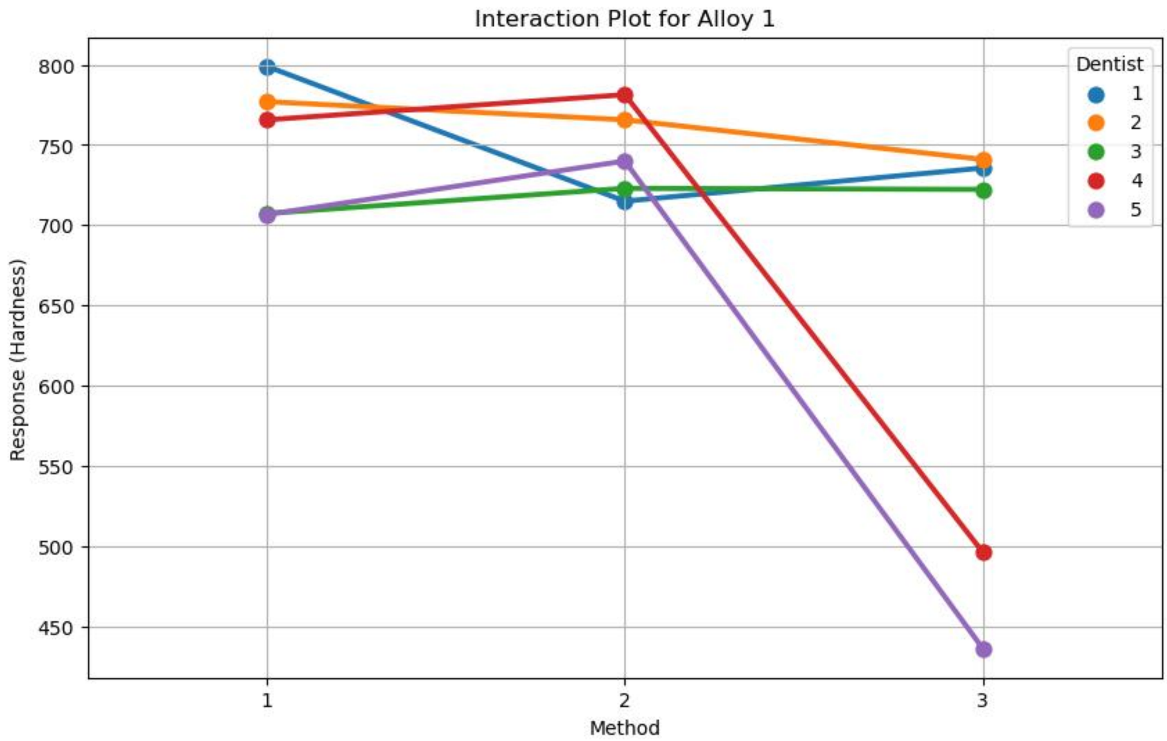

Figure 13:Interaction Plot for Alloy 1

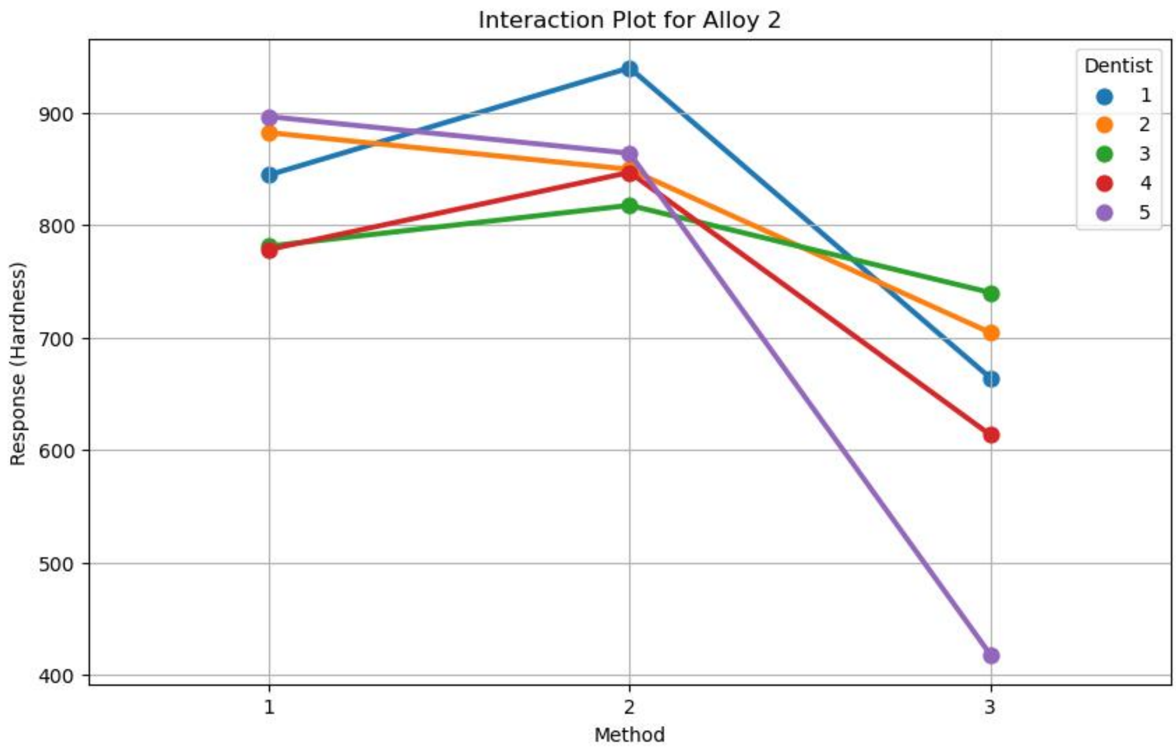

Figure 14:Interaction Plot for Alloy 2

Conclusion:

We can see that hardness of metal implants in dental cavities low for Alloy 1 used for dentists 4 and 5, And for alloy 2 the hardness is lower for Method 3.

The point plot indicates that there is an interaction effect between Dentist and Method, with the lines representing different Dentists showing variation across the levels of Method. However, it seems that this interaction effect may not be as pronounced for Method 3 compared to the other methods for Alloy 2.

- ***How does the hardness of implants vary depending on dentists and methods together?***

Null and Alternate Hypotheses :

For each alloy type, the hypotheses are:

H0:

- There is no significant difference in the mean response among the different Dentists.
- There is no significant difference in the mean response among the different Methods.
- There is no interaction effect between Dentist and Method on the response.

H1:

- There is a significant difference in the mean response among the different Dentists.
- There is a significant difference in the mean response among the different Methods.
- There is an interaction effect between Dentist and Method on the response.

ANOVA Table for Alloys - Dentist & Methods:

ANOVA Table for Alloy 1 - Dentist:

	df	sum_sq	mean_sq	F	PR(>F)
C(Dentist)	4.0	106683.688889	26670.922222	1.977112	0.116567
Residual	40.0	539593.555556	13489.838889	NaN	NaN

ANOVA Table for Alloy 2 - Dentist:

	df	sum_sq	mean_sq	F	PR(>F)
C(Dentist)	4.0	5.679791e+04	14199.477778	0.524835	0.718031
Residual	40.0	1.082205e+06	27055.122222	NaN	NaN

Table 16: ANOVA Table for Alloys - Dentist

ANOVA Table for Alloy 1 - Method:

	df	sum_sq	mean_sq	F	PR(>F)
C(Method)	2.0	148472.177778	74236.088889	6.263327	0.004163
Residual	42.0	497805.066667	11852.501587	NaN	NaN

ANOVA Table for Alloy 2 - Method:

	df	sum_sq	mean_sq	F	PR(>F)
C(Dentist)	4.0	5.679791e+04	14199.477778	0.524835	0.718031
Residual	40.0	1.082205e+06	27055.122222	NaN	NaN

Table 17: ANOVA Table for Alloys - Methods

Interaction Plot of Response by Dentist and Method for Alloys:

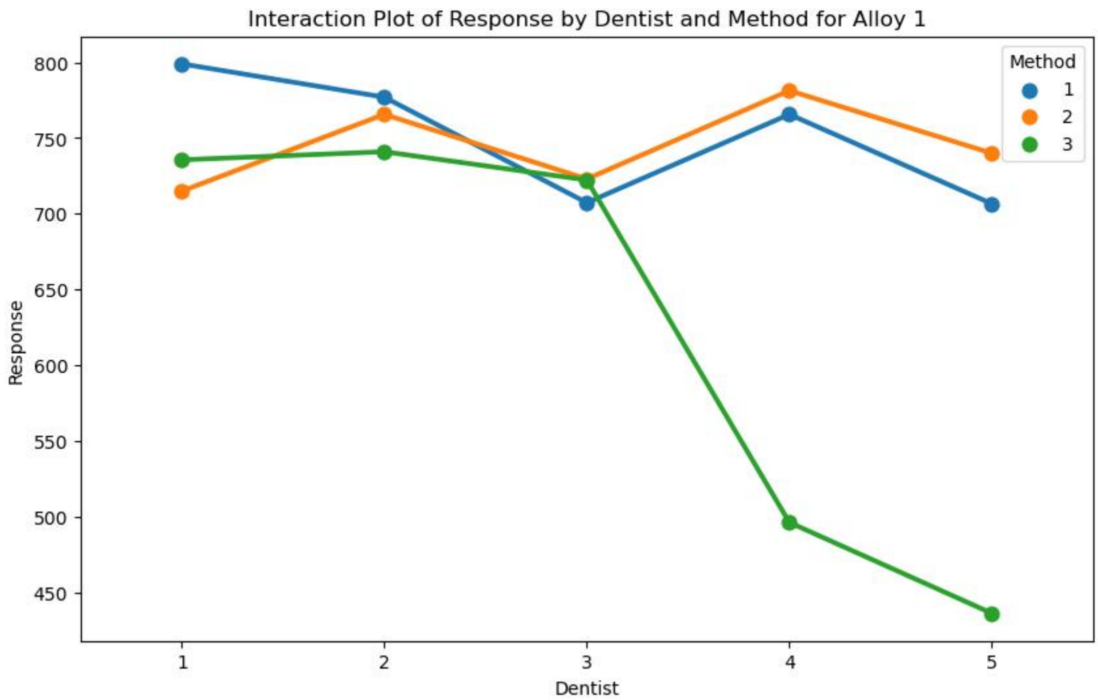

Figure 15:Interaction Plot of Response by Dentist and Method for Alloy 1

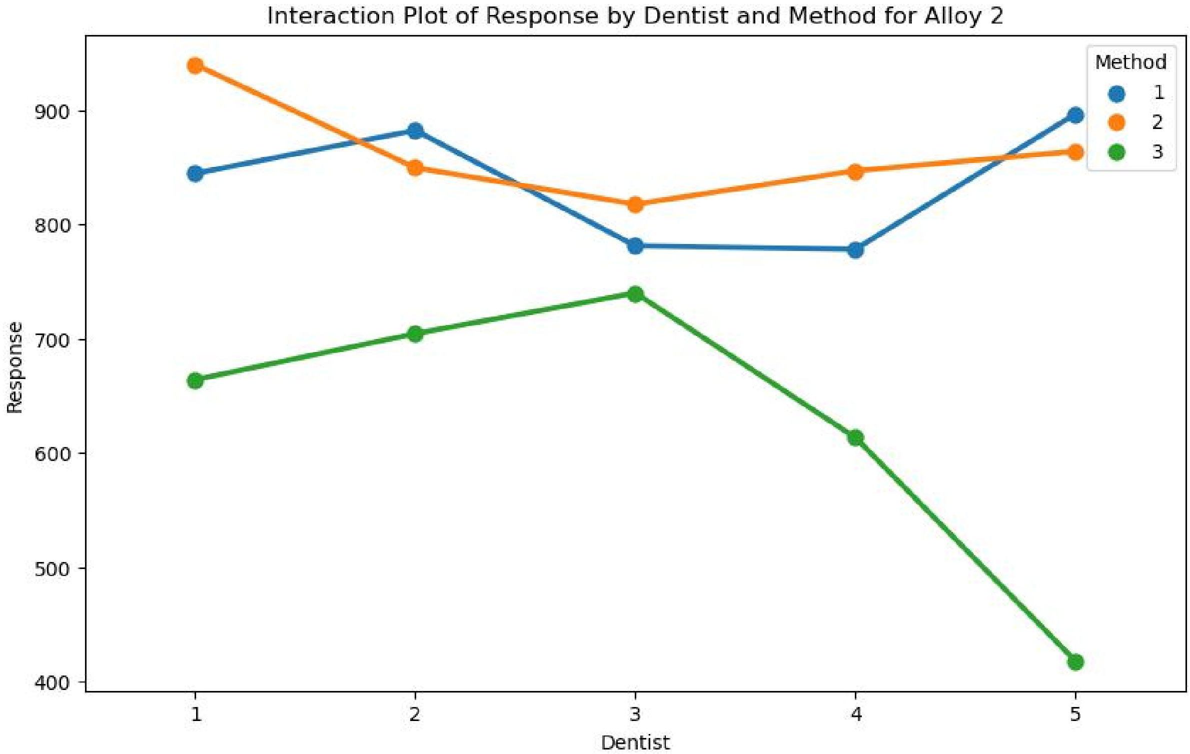

Figure 16:Interaction Plot of Response by Dentist and Method for Alloy 2

ANOVA results for Alloy 1:

	df	sum_sq	mean_sq	F	PR(>F)
C(Dentist)	4.0	106683.688889	26670.922222	3.899638	0.011484
C(Method)	2.0	148472.177778	74236.088889	10.854287	0.000284
C(Dentist):C(Method)	8.0	185941.377778	23242.672222	3.398383	0.006793
Residual	30.0	205180.000000	6839.333333	NaN	NaN

Table 18: ANOVA results for Alloy 1

ANOVA results for Alloy 2:

	df	sum_sq	mean_sq	F	PR(>F)
C(Dentist)	4.0	56797.911111	14199.477778	1.106152	0.371833
C(Method)	2.0	499640.400000	249820.200000	19.461218	0.000004
C(Dentist):C(Method)	8.0	197459.822222	24682.477778	1.922787	0.093234
Residual	30.0	385104.666667	12836.822222	NaN	NaN

Table 19: ANOVA results for Alloy 1

Conclusion:

For Alloy 1:

- Dentist: The p-value (0.011484) indicates a significant effect of different dentists on the hardness of the dental implants. This means that the hardness of the implants varies depending on which dentist performed the procedure.

- Method: The p-value (0.000284) indicates a significant effect of different methods on the hardness of the dental implants. This means that the method used to perform the procedure affects the hardness of the implants.
- Interaction: The p-value (0.006793) indicates a significant interaction effect between dentist and method. This means that the effect of the method on the hardness of the implants depends on which dentist performed the procedure.

For Alloy 2:

- Dentist: The p-value (0.371833) indicates no significant effect of different dentists on the hardness of the dental implants. This means that the hardness of the implants does not vary significantly depending on which dentist performed the procedure.
- Method: The p-value (0.000004) indicates a significant effect of different methods on the hardness of the dental implants. This means that the method used to perform the procedure affects the hardness of the implants.
- Interaction: The p-value (0.093234) indicates no significant interaction effect between dentist and method. This means that the effect of the method on the hardness of the implants does not significantly depend on which dentist performed the procedure.