Inferential Statistics Report

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PROBLEM 1

QUESTION:

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.

TABLE 1: Team data

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

Based on the above data, answer the following questions.

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

1.2 What is the probability that a player is a forward or a winger?

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

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

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

Solution:

Let P(I) be the Probability of a randomly chosen player would suffer from an injury.

P(I) = Total no. of Players injured / Total no. of players

Total no. of Players injured = 145

Total no. of players = 235

P(I) = 145/235 = 0.617

Probability of a randomly chosen player would suffer from an injury = 0.617 (61.7% chance)

1.2 What is the probability that a player is a forward or a winger?

Solution:

Let P(FW) be the Probability of a randomly chosen player is a forward or a winger.

P(FW) = (Total Forward Players ✚ Total Wingers) / Total no. of players

Total no. of Forward Players = 94

Total no. of Wingers = 29

Total Forward Players ✚ Total Wingers = 123

Total no. of players = 235

P(FW) = 123/235 = 0.523

Probability of a randomly chosen player is a forward or a winger = 0.523 (52.3% chance)

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

Solution:

Let P(SI) be the Probability of a randomly chosen player plays in a striker position and has a foot injury.

P(SI) = Total no. of injured Strikers / Total no. of players

Total no. of injured Strikers = 45

Total no. of players = 235

P(SI) = 45/235 = 0.191

Probability of a randomly chosen player plays in a striker position and has a foot injury = 0.191 (19.1% chance)

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

Solution:

Let P(IS) be the probability of a randomly chosen injured player is a striker.

P(IS) = Total no. of injured Strikers / Total no. of Injured players

Total no. of injured Strikers = 45

Total no. of Injured players = 145

P(SI) = 45/145 = 0.310

Probability of a randomly chosen injured player is a striker = 0.310 (31% chance)

PROBLEM 2

QUESTION:

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; Answer the questions below based on the given information; **(Provide an appropriate visual representation of your answers, without which marks will be deducted)**

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

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

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

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

Given:

Mean (mu) = 5

Standard Deviation (sigma) = 1.5

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

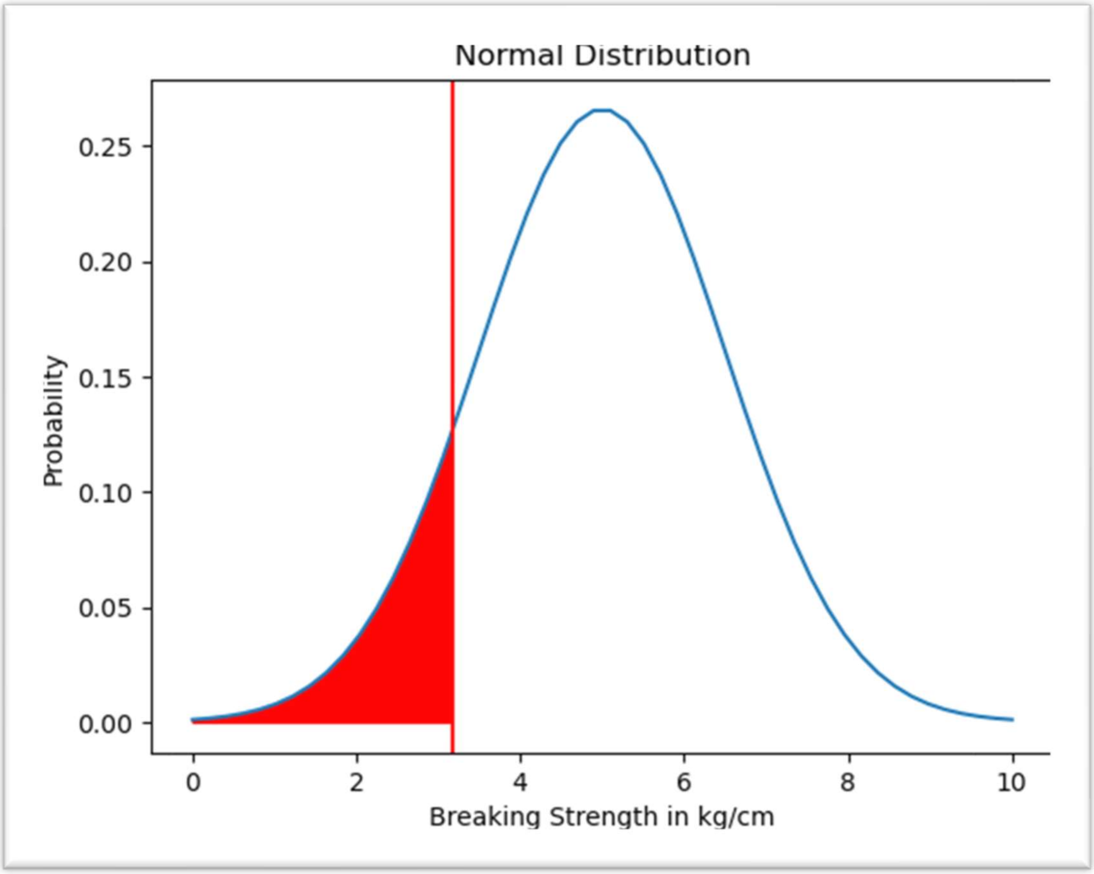
Solution:

To calculate the probability density, we can use the norm.cdf function of scipy.stats in python.

P(X < 3.17) = norm.cdf(3.17,mu,sigma) = 0.1112

Proportion of the gunny bags have a breaking strength of less than 3.17 kg per sq.cm = 11.12%

Fig.1 Graph 2.1



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

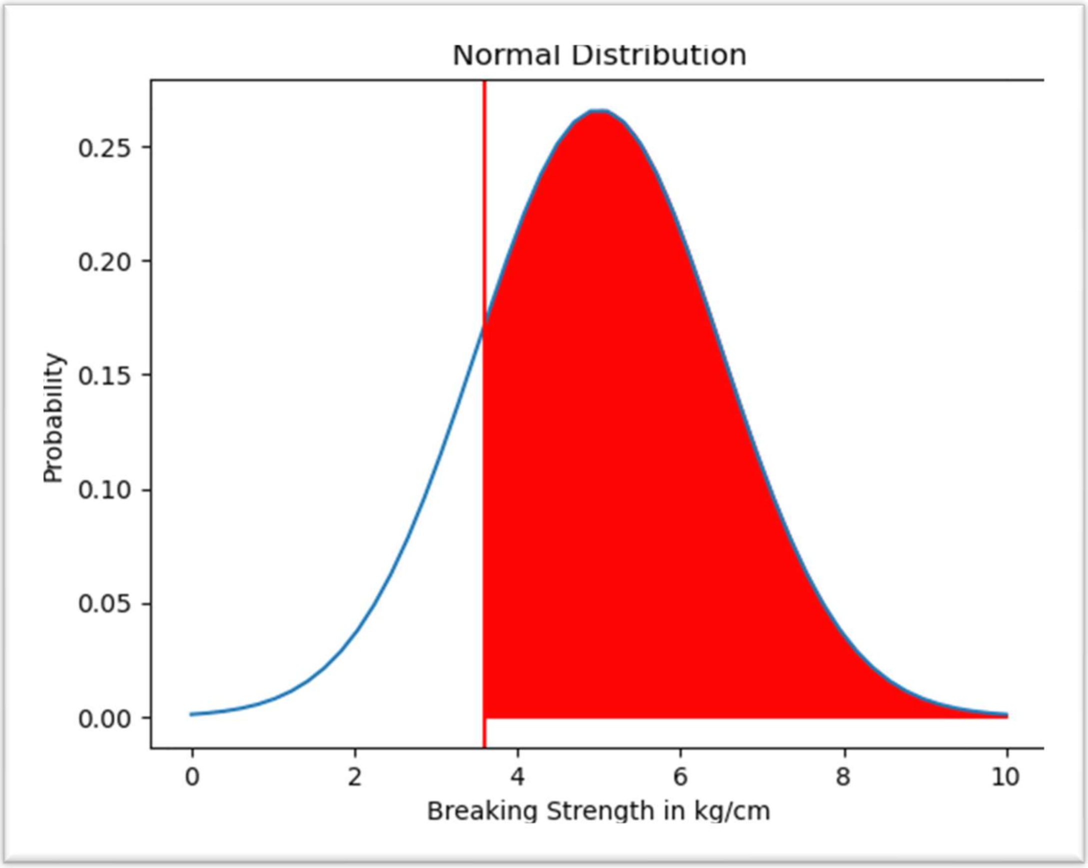
Solution:

To calculate the probability density, we can use the norm.cdf function of scipy.stats in python

P(X >= 3.6) = 1 – P(X<3.6) = 0.8247

Proportion of the gunny bags have a breaking strength of at least 3.6 kg per sq.cm = 82.47%

Fig.2 Graph 2.2



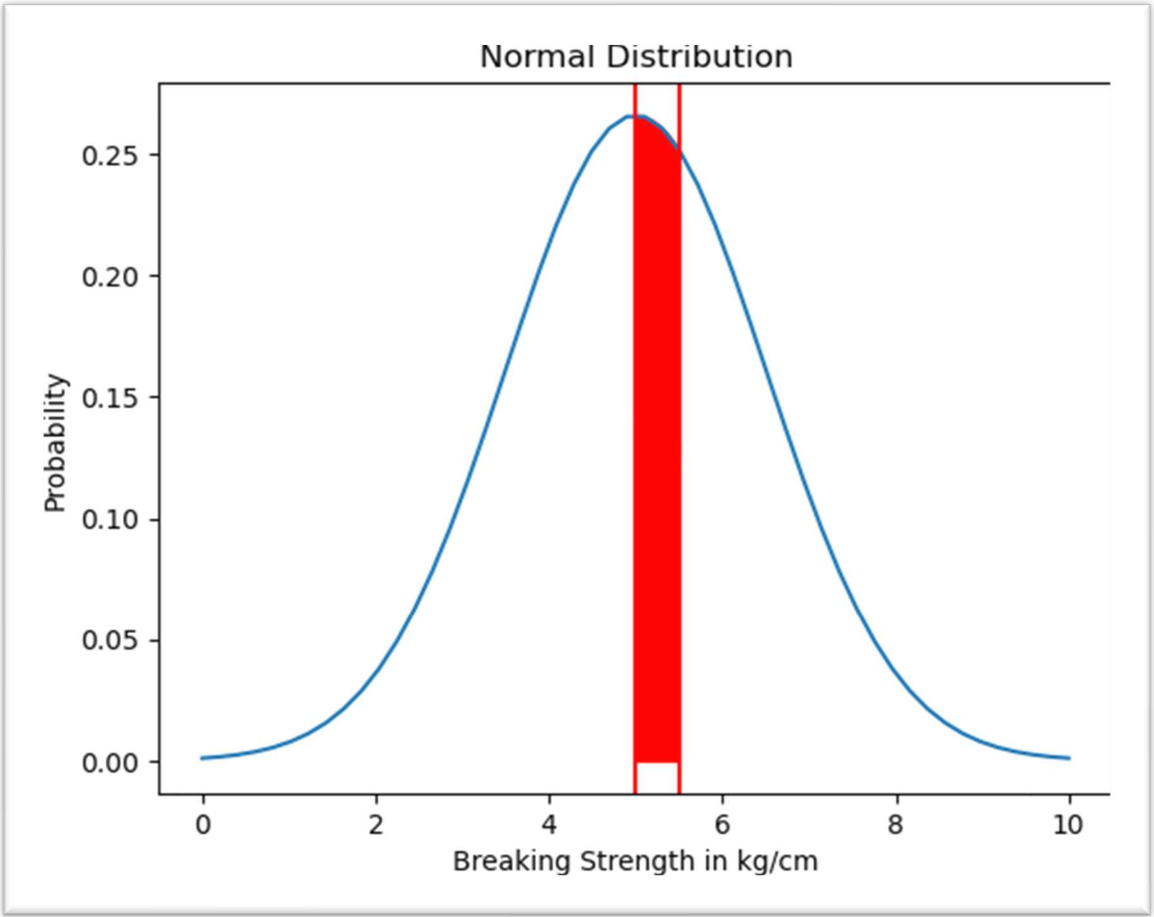
2.3 What proportion of the gunny bags have a breaking strength between 5 and 5.5 kg per sq cm.?

To calculate the probability density, we can use the norm.cdf function of scipy.stats in python

$P(5 < X < 5.5) = P(X<5.5) – P(X<5) = 0.1306$

Proportion of the gunny bags have a breaking strength between 5 and 5.5 kg per sq.cm = 13.06%

Fig.3 Graph 2.3



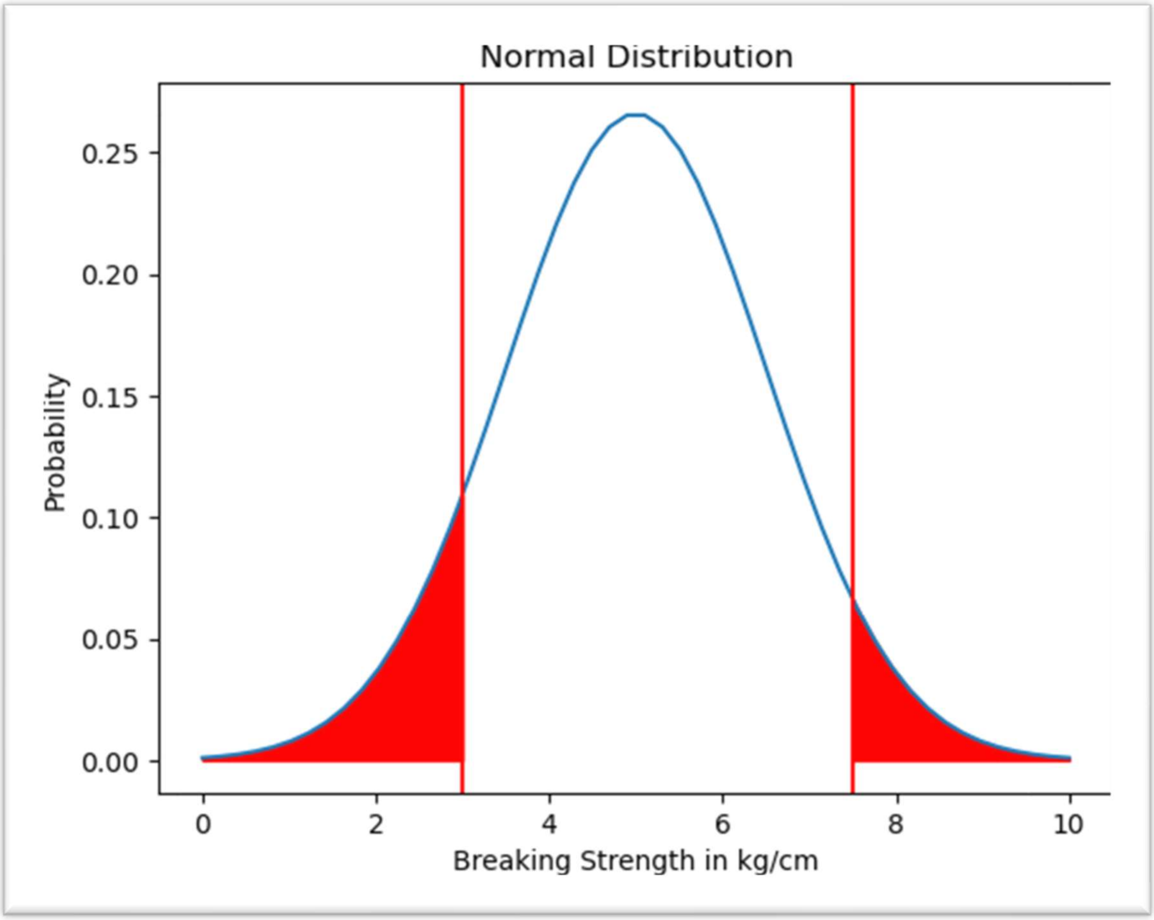
2.4 What proportion of the gunny bags have a breaking strength NOT between 3 and 7.5 kg per sq cm.?

To calculate the probability density, we can use the norm.cdf function of scipy.stats in python

P (X < 3 and X > 7.5) = P (X<3) + (1 - P (X<7.5)) = 0.139

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

Fig.4 Graph 2.4



PROBLEM 3

QUESTION:

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. Use the data provided to answer the following (assuming a 5% significance level);

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

3.2 Is the mean hardness of the polished and unpolished stones the same?

Data Overview:

Preview of the Dataset:

Fig.5 First 5 rows of the dataset1

	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

Shape:

- There are 75 rows and 2 columns
- There are no null values in this dataset.

Basic Information:

Fig.6 Basic Info1

```
<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
```

Numerical Statistics:

Fig.7 Numerical Statistics1

	count	mean	std	min	25%	50%	75%	max
Unpolished	75.0	134.110527	33.041804	48.406838	115.329753	135.597121	158.215098	200.161313
Treated and Polished	75.0	147.788117	15.587355	107.524167	138.268300	145.721322	157.373318	192.272856

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

Null Hypothesis : The Mean hardness index of unpolished stones is greater than or equal to 150. ($\mu \geq 150$)

Alternate Hypothesis : The Mean hardness index of unpolished stones is lesser than 150. ($\mu < 150$)

- Level of Significance $\alpha = 0.05$
- Normally distributed population and Sample size = 75 >30
- Population standard deviation is known - No

- We can use 1-sample T-test for this problem.
- The ttest_1samp() function of Scipy will be used to compute the test statistic and p-value.
- By performing the 1-Sample T-test, the values of test-statistic and p-values are obtained.

Fig.8 T-Test 3.1

```
1-Sample T-test
The test_stat is  -4.164629601426757
The p-value is  4.171286997419652e-05
```

- As the p-value(4.171286e-05) is much less than the level of significance(α = 0.05), we can reject the null hypothesis at 95% confidence.
- We have enough statistical evidence to say, that mean hardness index of unpolished stones is less than 150. So, Unpolished stones are not suitable for printing. Hence, Zingaro stone printing company's assumption is correct.

3.2 Is the mean hardness of the polished and unpolished stones the same?

Null Hypothesis **:** The Mean hardness index of unpolished stones and polished stones are equal.($\mu1 = \mu2$)

Alternate Hypothesis **:** The Mean hardness index of unpolished stones and polished stones are unequal. ($\mu1 \neq \mu2$)

- Level of Significance α = 0.05
- Normally distributed population and Sample size = 75 >30.

- Independent populations - As we are taking random samples for two different stones, the two samples are from two independent populations.
- We can use 2 Independent-Sample T-test for this problem.
- The ttest_ind() function of Scipy will be used to compute the test statistic and p-value.
- By performing the 2 Independent-Sample T-test, the values of test-statistic and p-values are obtained.

Fig.9 2samp T-Test 3.1

```
2 Independent-Sample T-test
The test_stat is  -3.242232050141405З
The p-value is  0.0014655150194628353
```

- As the p-value(0.00146) is much less than the level of significance(α = 0.05), we can reject the null hypothesis at 95% confidence.
- We have enough statistical evidence to say, that **mean hardness index of unpolished and polished stones are unequal and significantly differs.** ($\mu1 \neq \mu2$)

PROBLEM 4

QUESTION:

Dental implant data: 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.

4.1 How does the hardness of implants vary depending on dentists?

4.2 How does the hardness of implants vary depending on methods?

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

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

Data Overview:

Preview of the Dataset:

Fig.10 First 5 rows of the dataset2

	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

Shape:

There are 90 rows and 5 columns

Basic Information:

Fig.11 Basic Info2

```
<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
```

The datatype of these columns – Dentist, Method, Aloy is int64.

Fig.12 Datatype before correction

```
1    18
2    18
3    18
4    18
5    18
Name: Dentist, dtype: int64
```

```
1    30
2    30
3    30
Name: Method, dtype: int64
```

```
1    45
2    45
Name: Alloy, dtype: int64
```

After converting these columns into categorical columns,

Fig.13 Basic info after correction

```
<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     int64
 4   Response  90 non-null     int64
dtypes: category(3), int64(2)
memory usage: 2.3 KB
```

Numerical Statistics:

Fig.14 Numerical Statistics2

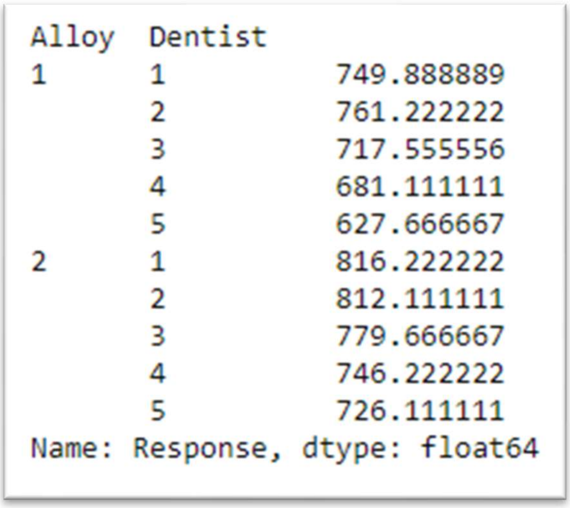
	count	mean	std	min	25%	50%	75%	max
Dentist	90.0	3.000000	1.422136	1.0	2.0	3.0	4.0	5.0
Method	90.0	2.000000	0.821071	1.0	1.0	2.0	3.0	3.0
Alloy	90.0	1.500000	0.502801	1.0	1.0	1.5	2.0	2.0
Temp	90.0	1600.000000	82.107083	1500.0	1500.0	1600.0	1700.0	1700.0
Response	90.0	741.777778	145.767845	289.0	698.0	767.0	824.0	1115.0

4.1 How does the hardness of implants vary depending on dentists?

Solution:

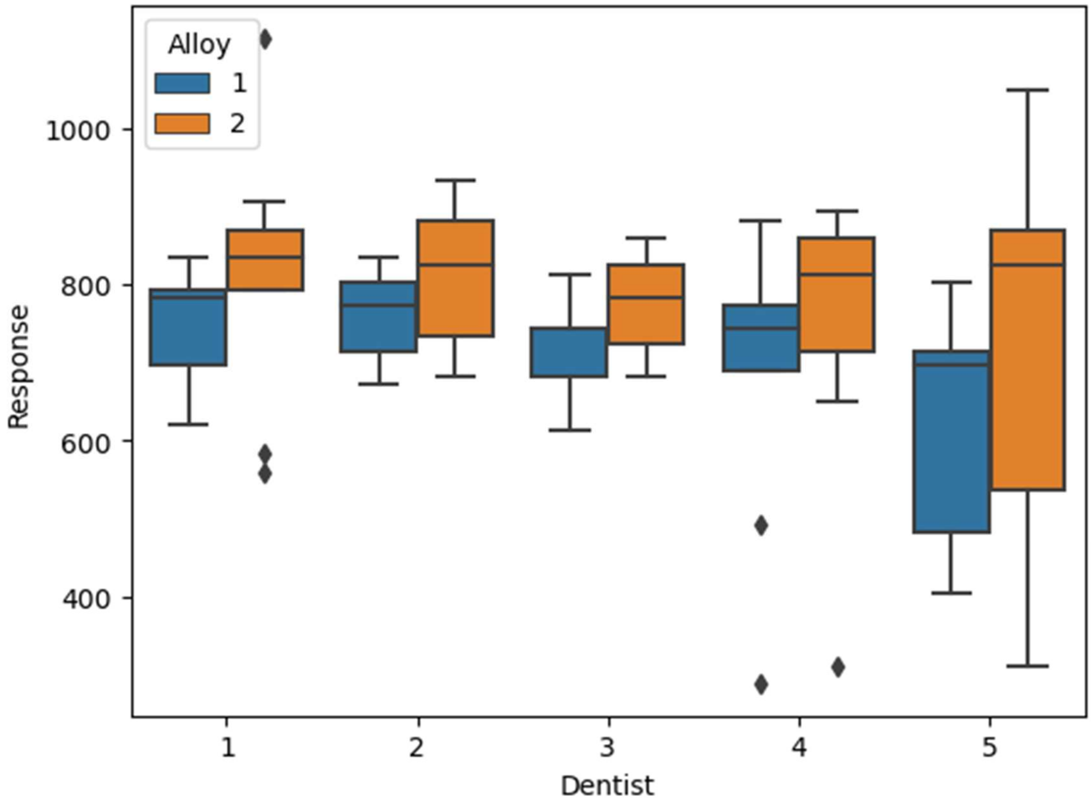
Visual Representation:

Fig.15 Alloy-Dentist Groupby



```
Alloy  Dentist
1      1          749.888889
       2          761.222222
       3          717.555556
       4          681.111111
       5          627.666667
2      1          816.222222
       2          812.111111
       3          779.666667
       4          746.222222
       5          726.111111
Name: Response, dtype: float64
```

Fig.16 Dentist vs Response vs Alloy



Assumptions of the test:

Shapiro-Wilk's test

For Alloy 1:

Null Hypothesis (H0) : The Mean Implant hardness for Alloy 1 follows normal distribution.

Alternate Hypothesis (Ha) : The Mean Implant hardness for Alloy 1 does not follows normal distribution.

Since p-value(1.19e-05) of the test is smaller than the significance level(0.05), we can reject the null hypothesis and the response doesn't follows the normal distribution.

For Alloy 2:

Null Hypothesis (H0) : The Mean Implant hardness for Alloy 2 follows normal distribution.

Alternate Hypothesis (Ha) : The Mean Implant hardness for Alloy 2 does not follows normal distribution.

Since p-value(0.0004) of the test is smaller than the significance level(0.05), we can reject the null hypothesis and the response doesn't follows the normal distribution.

Levene's test:

Null Hypothesis (H0) : All the population variances are equal

Alternate Hypothesis (Ha) : At least one variance is different from the rest

Since p-value(0.0078) of the test is smaller than the significance level(0.05), we can reject the null hypothesis.

Case 1 (Alloy 1):

Null Hypothesis (H0) : The Mean Implant hardness is same across all the dentists for Alloy 1.

Alternate Hypothesis (Ha) : At least one pair of dentists is different from the rest for Alloy 1.

By performing One way ANOVA for Response variable for Alloy 1,

Fig.17 Dentist_Alloy1

----------------------------Alloy 1------------------------------

	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

The p-value (0.116567) is greater than the signifance level ($\alpha = 0.05$). So, we fail to reject the null hypothesis.

The Mean implant hardness is same across all the dentists for Alloy 1.

Case 2 (Alloy 2):

Null Hypothesis (H0) : The Mean Implant hardness is same across all the dentists for Alloy 2.

Alternate Hypothesis (Ha) : At least one pair of dentists is different from the rest for Alloy 2.

By performing One way ANOVA for Response variable for Alloy 2,

Fig.18 Dentist_Alloy2

```
----------------------------Alloy 2------------------------------
                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
```

The p-value (0.718031) is greater than the signifance level (α = 0.05). So, we fail to reject the null hypothesis.

The Mean implant hardness is same across all the dentists for Alloy 2.

INFERENCES:

The Mean implant hardness is same across all the dentists for Alloy 1 and Alloy 2.

4.2 How does the hardness of implants vary depending on methods?

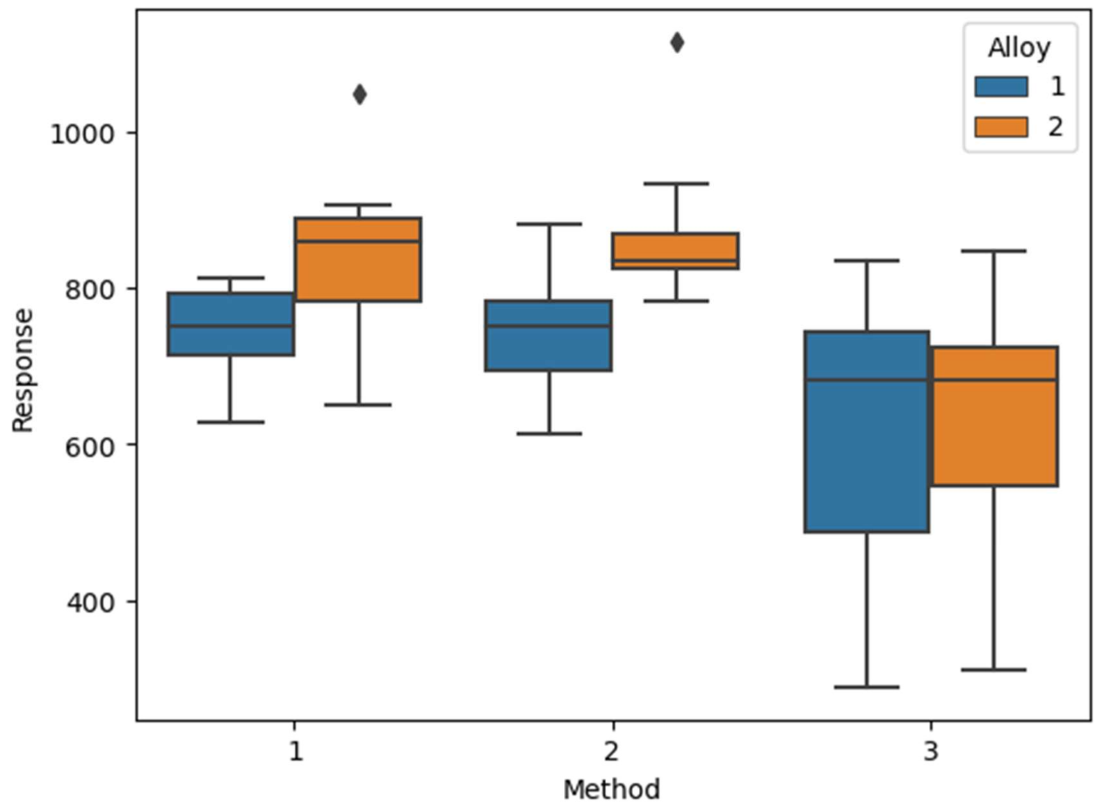
Solution:

Visual Representation:

Fig.19 Alloy-Methods Groupby

```
Alloy  Method
1      1         751.133333
       2         745.000000
       3         626.333333
2      1         836.666667
       2         863.666667
       3         627.866667
Name: Response, dtype: float64
```

Fig.20 Methods vs Response vs Alloy



Assumptions of the test:

Shapiro-Wilk’s test

For Alloy 1:

Null Hypothesis (H0) : The Mean Implant hardness for Alloy 1 follows normal distribution.

Alternate Hypothesis (Ha) : The Mean Implant hardness for Alloy 1 does not follows normal distribution.

Since p-value(1.19e-05) of the test is smaller than the significance level(0.05), we can reject the null hypothesis and the response doesn't follows the normal distribution.

For Alloy 2:

Null Hypothesis (H0) : The Mean Implant hardness for Alloy 2 follows normal distribution.

Alternate Hypothesis (Ha) : The Mean Implant hardness for Alloy 2 does not follows normal distribution.

Since p-value(0.0004) of the test is smaller than the significance level(0.05), we can reject the null hypothesis and the response doesn't follows the normal distribution.

Levene’s test:

Null Hypothesis (H0) : All the population variances are equal

Alternate Hypothesis (Ha) : At least one variance is different from the rest

Since p-value(0.004) of the test is smaller than the significance level(0.05), we can reject the null hypothesis.

Case 1 (Alloy 1):

Null Hypothesis (H0) : The Mean Implant hardness is same across all the methods for Alloy 1.

Alternate Hypothesis (Ha) : At least one pair of methods is different from the rest for Alloy 1.

By performing One way ANOVA for Response variable for Alloy 1,

Fig.21 Method_Alloy1

```
----------------------------Alloy 1-----------------------------
               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
```

The p-value (0.004163) is smaller than the signifance level ($\alpha = 0.05$). So, we can reject the null hypothesis and have evidence for alternate hypothesis.

At least one pair of methods is different from the rest for Alloy 2.

Case 2 (Alloy 2):

Null Hypothesis (H0) : The Mean Implant hardness is same across all the methods for Alloy 2.

Alternate Hypothesis (Ha) : At least one pair of methods is different from the rest for Alloy 2.

By performing One way ANOVA for Response variable for Alloy 2,

Fig.22 Method_Alloy2

----------------------------Alloy 2-------------------------------

	df	sum_sq	mean_sq	F	PR(>F)
C(Method)	2.0	499640.4	249820.200000	16.4108	0.000005
Residual	42.0	639362.4	15222.914286	NaN	NaN

The p-value (0.000005) is smaller than the signifance level ($\alpha = 0.05$). So, we can reject the null hypothesis and have evidence for alternate hypothesis.

At least one pair of methods is different from the rest for Alloy 2.

By perfoming **Multiple Comparison test (Tukey HSD)**, we can clearly identify which method is different from other groups.

Null Hypothesis (H0) : $\mu 1 = \mu 2$ (and) $\mu 1 = \mu 3$ (and) $\mu 1 = \mu 2$

Alternate Hypothesis (Ha) : $\mu 1 \neq \mu 2$ (or) $\mu 1 \neq \mu 3$ (or) $\mu 2 \neq \mu 3$

Fig.23 Tukey HSD

```
------------------------Alloy 1------------------------
  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
---------------------------------------------------------
------------------------Alloy 2------------------------
  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
---------------------------------------------------------
```

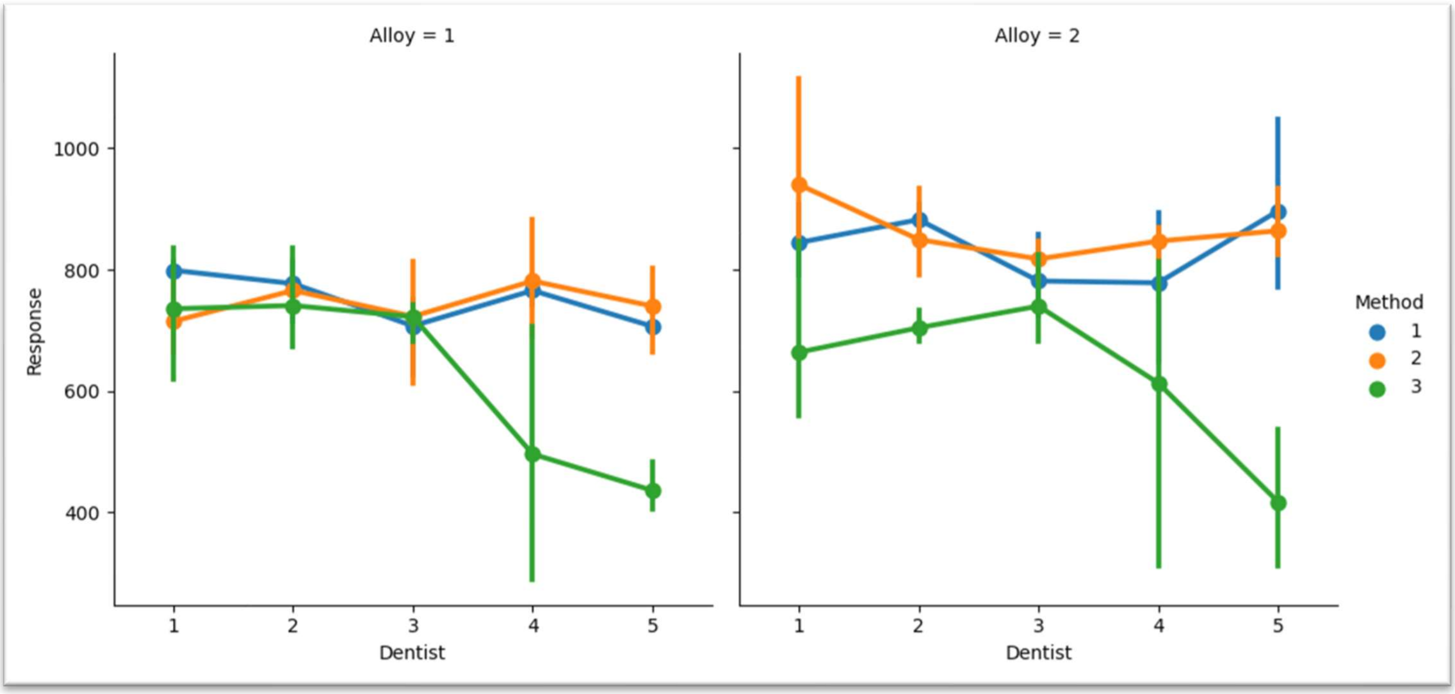
As the p-value for comparing the mean hardness for the pair Method1 - Method3 and Method2 - Method3 is less than theh significance level (α=0.05), the null hypothesis can be rejected.

INFERENCES:

Thus, we can say that the mean hardness for Method1 and Method2 is similar but Method3 is significantly different from the other two methods.

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

Fig.24 Interaction Plot



INFERENCES:

- Method 3 shows a significant decline in response across dentists
- Method 1 and Method 2 share a similar effect with respect to dentists and implant hardness.
- A strong decline in implant hardness particularly in Dentists 4 and Dentist 5.
- By perfoming **Multiple Comparison test (Tukey HSD)**, we can clearly identify which combinations is different from other groups

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

For Alloy 1:

Null Hypothesis (H0) : The effect of 'Dentist' on 'Method' does not depend on the effect of Implant hardness (Response variable) for Alloy 1(no interaction effect)

Alternate Hypothesis (Ha) : There is an interaction effect between 'Dentist' and 'Method' on Implant hardness for Alloy 1 (Response variable)

Fig.25 2-way ANOVA for Alloy1

```
----------------------------------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
```

C(Dentist): The p-value (0.011484) is greater than the signifance level ($\alpha = 0.05$). So, we fail to reject the null hypothesis.

C(Method): The p-value (0.000284) is smaller than the signifance level ($\alpha = 0.05$). So, we can reject the null hypothesis.

C(Dentist):C(Method) : The p-value (0.006793) is smaller than the signifance level ($\alpha = 0.05$). So, we can reject the null hypothesis.

For Alloy 2:

Null Hypothesis (H0) : The effect of 'Dentist' on 'Method' does not depend on the effect of Implant hardness (Response variable) for Alloy 2(no interaction effect)

Alternate Hypothesis (Ha) : There is an interaction effect between 'Dentist' and 'Method' on Implant hardness for Alloy 2 (Response variable)

Fig.26 2-way ANOVA for Alloy2

----------------------------------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

C(Dentist): The p-value (0.371833) is greater than the signifance level (α = 0.05). So, we fail to reject the null hypothesis.

C(Method): The p-value (0.000004) is smaller than the signifance level (α = 0.05). So, we can reject the null hypothesis.

C(Dentist):C(Method) : The p-value (0.093234) is greater than the signifance level (α = 0.05). So, we fail to reject the null hypothesis.

By perfoming **Multiple Comparison test (Tukey HSD)**, we can clearly identify which combinations is different from other groups.

Fig.27 Tukey HSD for Dentists

```
-----------------------Alloy 1-----------------------
  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
-----------------------------------------------------
-----------------------Alloy 2-----------------------
  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
----------------------------------------------------
```

INFERENCE:

- All the Dentists combinations are same and are not having impact on hardness levels

Fig.28 Tukey HSD for Methods

Alloy 1

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

Alloy 2

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

INFERENCE:

- We can clearly see that, Method 3 is having impact on the hardness level.
- For Alloy1 and Alloy2, pairs of (Method 1 and Method 3) and (Method 2 and Method 3) are having impact.