ADVANCED STATISTICS BUSINESS REPORT

Fasna.PP

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Table

Data sources -

1-Dental Hardness data.xlsx

Dentist: This column likely contains the names or identifiers of dentists Who participated in the data collection or study.

Method: This column may represent the method or technique used testing dental materials.

Alloy: This column likely contains information about the specific dental materials .

Temp: This column appears to represent the temperature at which the testing was conducted.

Response: This column might represent the recorded response, possibility Related to the hardness of the dental material.

2-Zingaro_Company.csv

Unpolished:This column likely represents numerical data associated with unpolished materials or products.

Treated and Polished: This column appears to represent numerical data associated with materials or products that have been treated and polished

Problem -1

A physiotherapist with a male football team is interested in studying the relationship between foot injuries and positions at which the players play. The data collected is summarized in the table below, Answer the questions based on the table

	Striker	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 set

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

From the given table we can see that the, number of players injured is 145, and the total number of players is 235. Hence the probability that a randomly chosen player is injured is;

P (Injured) = 145/235 = 0.617

So, the probability that a randomly chosen player would suffer an injury is approximately 0.6170, or about 61.70%.

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

Total number of players that are forwards or wingers is 123 (94 + 29), and total number of players under study is 235. Hence, the probability that a

randomly chosen player is a forward or a winger is;

P (Forward OR Winger) = (94+29)/235 = 0.523

So, the probability that a player is either a forward or a winger is approximately 0.5234, or about 52.34%.

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

Note that this is a joint probability problem, where two conditions are being satisfied simultaneously. The number of players who have a foot injury and who play in striker position is 45. The total number of players under consideration is 235. Hence the probability that a player is a striker and is injured is;

P (Striker AND Injured) = 45/235 = 0.1915

So, the probability that a randomly chosen player plays in a striker position and has a foot injury is approximately 0.1915, or about 19.15%.

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

Note that this is a conditional probability problem, because not all players and considered. Given that the chosen player is injured we need to find the probability that he is a striker.

Since there are 145 injured players. The conditional probability is;

P (Striker|Injured) = 45/145 = 0.3103

So, the probability that a randomly chosen injured player is a striker is approximately 0.3103, or about 31.03%.

Problem-2

The breaking strength of gunny bags used for packaging cement is normally distributed with a mean of 5 kg per sq. centimetre and standard deviation of 1.5 kg per sq. centimetre. 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 appropriate visual representation of your answers, without which marks will be deducted)**

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

Using the mean and the standard deviation of the normal distribution, we need to find the probability of a gunny bag having a breaking strength less than 3.17 kg per sq cm.(cumulative probability calculated using stats.norm.cdf function).

P (Breaking strength < 3.17) = 0.1112

for visualization

Find the minimum and Maximum points

max_value=mean+3(standard deviation)=5+3(1.5)=9.5 mini_value=mean-3(standard deviation)=5-3(1.5)=0.5

visualize probability of breaking strength less than 3.17

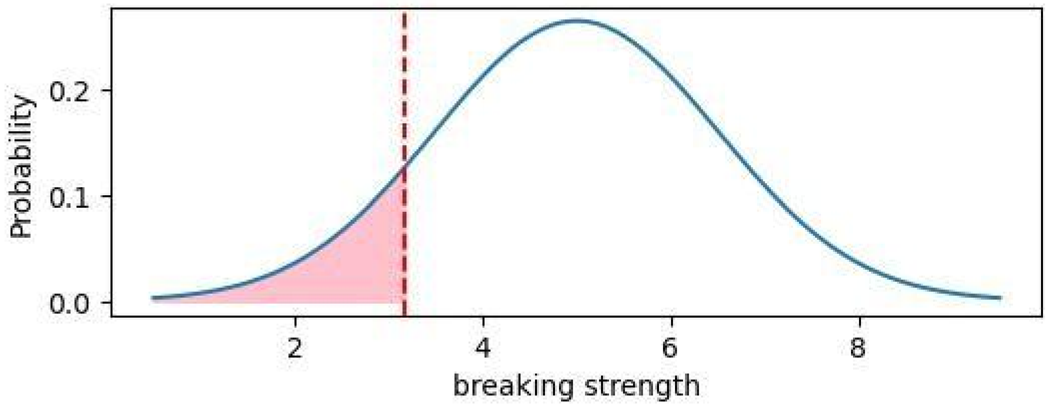

Figure 1 **pink Area indicates required probability**

2.2 What proportion of the gunny bags have a breaking strength at least

3.6 kg per sq cm.?

Using the mean and the standard deviation of the normal distribution, we need to find the probability of a gunny bag having a breaking strength at least 3.6 kg per sq cm.

P (Breaking strength > 3.6) = 1 - 0.1753 = 0.8247

(Cumulative probability calculated using stats.norm.cdf function).

visualize proportion of the gunny bags have a breaking strength at least 3.6 kg per sq cm

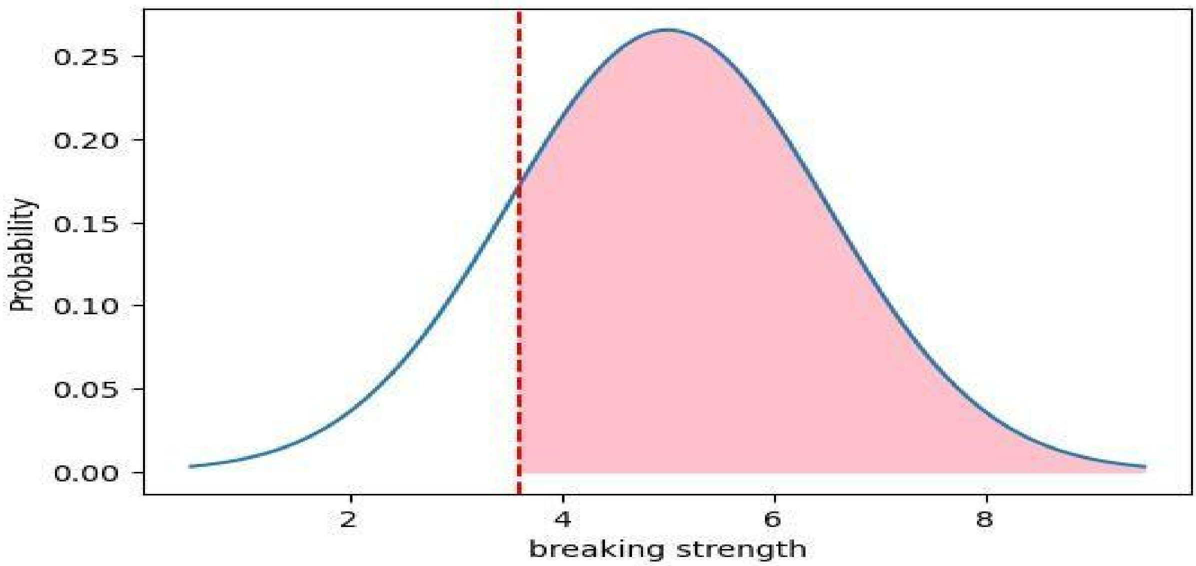

Figure 2 **Required probability indicated by pink shaded area.**

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

Using the mean and the standard deviation of the normal distribution, we need to find the probability of a gunny bag having a breaking strength between 5kg per sq cm and 5.5 kg per sq cm.

P (5 < Breaking strength < 5.5) = 0.6306 – 0.5 = 0.1306

(Cumulative probability calculated using stats.norm.cdf function).

visualize proportion of the gunny bags have a breaking strength between 5 and 5.5 kg per sq cm

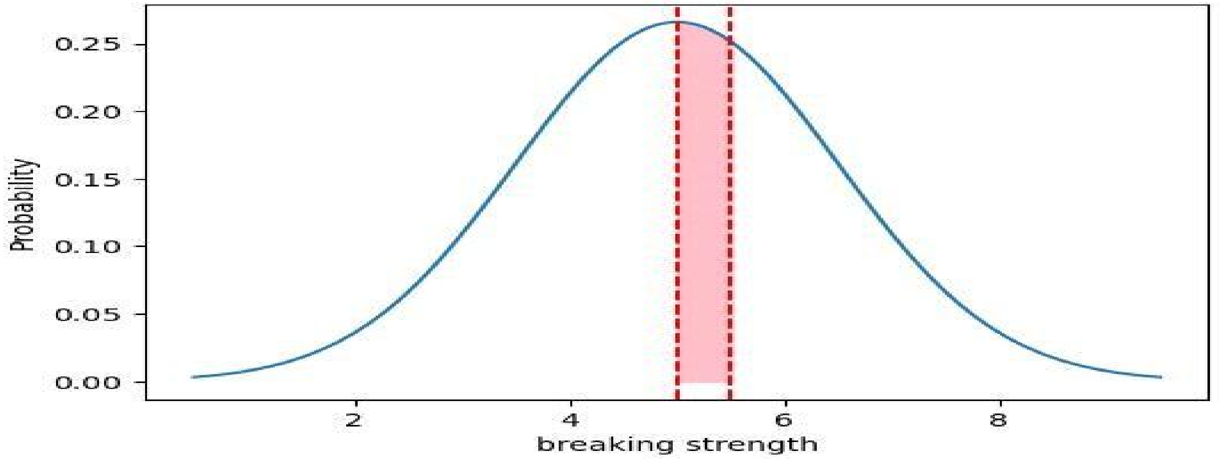

Figure 3 **Required Probability indicated by the pink shaded region.**

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

Using the mean and the standard deviation of the normal distribution, we need to find the probability of a gunny bag having a breaking strength.

(Cumulative probability calculated using stats.norm.cdf function).

1 – P (3 < Breaking strength < 7.5)=0.139 **visualize probability of a gunny bag having a breaking strength NOT between 3 and 7.5 kg per sq cm**

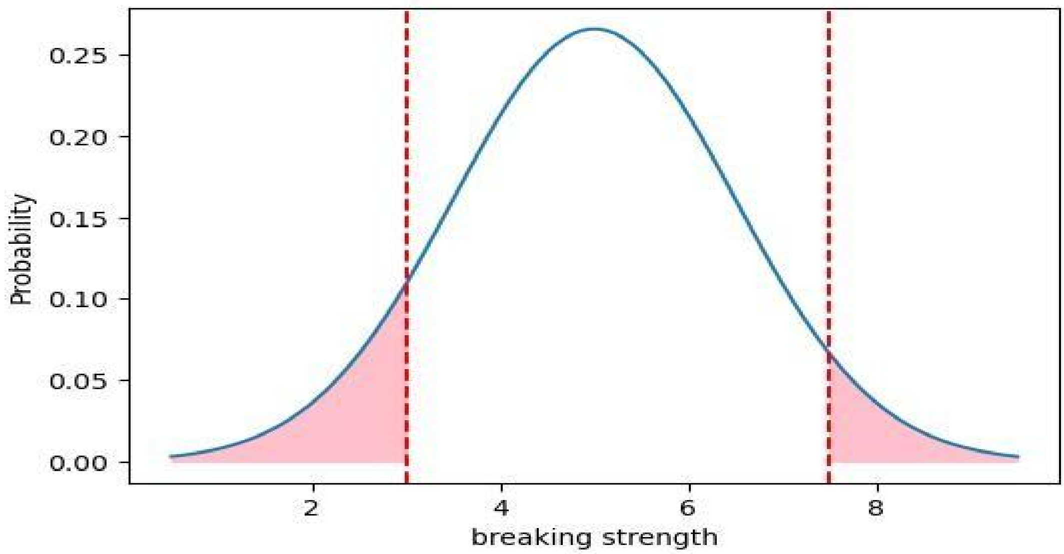

Figure 4 **pink shaded area indicates the required probability**

Problem-3

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

Read the data file

index	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-2-First 5 rows of data set

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

The hypothesis test is formulated as below,

H0 = The population mean BHI(Brinell's hardness) **for unpolished stones is at least 150 or (μu ≥ 150)**

H1 = The population mean BHI for unpolished stones is at least 150 or (μu < 150)

Looking at the Hypothesis formulation, find the test static value and p value using **1 sample T test** with a Level of Significance 0.05 (α = 5%).

Output -

test stat value: -4.1646

p_value: 0.0001

As observed above, the P-value is smaller than the level of significance. Hence, the Null Hypothesis that the unpolished stone surfaces have an average BHI of at least 150 is rejected.

Zingero is justified in concluding that the unpolished stones are not suitable for optimal level of printing.

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

H0: The population mean BHI for Polished stones and Unpolished stones is equal (μp = μu) or (μp - μu =0)

H1: The population mean BHI for Polished stones and Unpolished stones is not equal (μp ≠ μu) or (μp - μu ≠ 0)

Note that this is a **two-tailed test** with a Level of Significance of 0.05 (α = 5%).

Output -

the t-static value: 3.2422

p_value: 0.00147

P-value is smaller than the level of significance. The Null Hypothesis that the polished stone surfaces have a BHI equal to that of the unpolished stones will be rejected.

Average hardness of the polished and the unpolished stones is not equal.

Problem-4

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.

Read the data set

index	Dentist	Method	Alloy	Temp	Response
0	1.0	1.0	1.0	1500.0	813.0
1	1.0	1.0	1.0	1600.0	792.0
2	1.0	1.0	1.0	1700.0	792.0
3	1.0	1.0	2.0	1500.0	907.0
4	1.0	1.0	2.0	1600.0	792.0

Table-3-first 5 rows of the data set

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

"- State the null and alternate hypotheses - Check the assumptions of the hypothesis test. - Conduct the hypothesis test and compute the p-value Write down conclusions from the test results - In case the implant hardness differs, identify for which pairs it differs Note: 1. Both types of alloys cannot be considered together. You must conduct the analysis separately for the two types of alloys. 2. Even if the assumptions of the test fail, kindly proceed with the test."

State the null and alternate hypotheses

Hypothesis test formulation for Alloy 1

H01: The mean implant hardness is the same across different dentists with type 1 alloy.

HA1: Mean implant hardness is different for at least one pair of the dentists with type 1 alloy.

Hypothesis test formulation for Alloy 2

H01: The mean implant hardness is the same across different dentists with type 2 alloy.

HA1: Mean implant hardness is different for at least one pair of the dentists with type 2 alloy.

Check the assumptions of the hypothesis test.

In a one-way ANOVA test, we compare the means from several populations to test if there is any significance difference between them. The results from an ANOVA test are most reliable when the assumptions of normality and equality of variances are satisfied.

For testing of normality, **Shapiro-Wilk's test** is applied to the response variable.

For equality of variance**, Levene test** is applied to the response variable.

Test of Normality (Shapiro) for Type 1 Alloy for Dentist variable

H0 1: the implant hardness of "Dentist" variable within the "Type 1 Alloy" follows a normal distribution

HA 1:the implant hardness of "Dentist" variable within the "Type 1 Alloy" does not follow a normal distribution.

apply shapiro test for hardness of different Dentist within type 1 Alloy

Shapiro-Wilk Test static value: 0.9113541841506958 p-value: 0.3254688084125519
Shapiro-Wilk Test static value: 0.9642462134361267 p-value: 0.8415456414222717
Shapiro-Wilk Test static value: 0.8721169233322144 p-value: 0.12953516840934753
Shapiro-Wilk Test static value: 0.8368974328041077 p-value: 0.05333680287003517
Shapiro-Wilk Test static value: 0.8534296751022339 p-value: 0.08127813786268234

none of the cases, p-value is smaller than level of significance(0.05).Hence normality assumption is satisfied,

it means the implant hardness of "Dentist" variable within the "Type 1 Alloy" follows a normal distribution

Test of Normality (Shapiro) for Type 2 Alloy for Dentist variable

H0 2: the implant hardness of "Dentist" variable within the "Type 2 Alloy" follows a normal distribution

HA 2:the implant hardness of "Dentist" variable within the "Type 2 Alloy" does not follow a normal distribution.

apply shapiro test for hardness of different Dentist within type 2 Alloy

Shapiro-Wilk Test static value: 0.9039731621742249 pvalue: 0.27593979239463806
Shapiro-Wilk Test static value: 0.9392004013061523 pvalue: 0.5735077857971191
Shapiro-Wilk Test static value: 0.9340971112251282 pvalue: 0.5213080644607544
Shapiro-Wilk Test static value: 0.7613219022750854 pvalue: 0.007332688197493553
Shapiro-Wilk Test static value: 0.9131584167480469 pvalue: 0.33861100673675537

For one dentist, p-value is smaller than level of significance(0.05),other p value
s greater than 0.05,**which means the implant hardness of "Dentist" variabl e within the "Type 2 Alloy" follows a normal distribution,except one case dentist.We will proceed with ANOVA.**

Levene test of equal variance for Type 1 and Type 2 Alloy for Dentist variable

H0: variances for Type 1 and Type 2 Alloy with Dentist are equal
Ha: At least one variance is different from the rest

- create data frame with alloy type 1 metal implants
- apply levene test for type 1 Alloy with Dentist

variable **output**

The levene test static value: 1.3847146992797106 ,p value: 0.2565537418 543795

- create data frame with alloy type 2 metal implants
- apply levene test for type 2 Alloy with Dentist

variable **output**

levene test statistic value: 1.4456166464566966 ,p value: 0.23686777576 324952

Form above result for both alloy 1 and alloy 2 p value is greater than level of significance(0.05), we can conclude ,fail the reject the null hypothesis that the **variances of alloy 1 and alloy 2 with dentist are equal.**

We will proceed with ANOVA.

Since the level of significance is 5%, we can check from the below ANOVA output arrived at by using the anova_lm function from scipy. stats.

Conduct the hypothesis test and compute the p-value

Hypothesis test formulation for Alloy 1

H01: The mean implant hardness is the same across different dentists with type 1 alloy.

HA1: Mean implant hardness is different for at least one pair of the dentists with type 1 alloy.

- create a data frame with alloy 1 type metal implants
- Create the Anova table with function Dentist of alloy 1 type

	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

- Table-4-**Anova table with function Dentist of alloy 1 type**

Since p-value is greater than 0.05, we fail to reject the null hypothesis of equality. ***which is The mean implant hardness is the same across different dentists with type 1 alloy.***

Hypothesis test formulation for Alloy 2

H01: The mean implant hardness is the same across different dentists with type 2 alloy.

HA1: Mean implant hardness is different for at least one pair of the dentists with type 2 alloy.

- create a data frame with alloy 2 type metal implants
- Create the Anova table with function Dentist of Alloy 2 type

	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-5- **Anova table with function Dentist of Alloy 2 type** *the p-value is greater than level of significance(0.05) , **we fail to reject the null hypothesis of equality. which is The mean implant hardness is the same across different dentists with type 2 alloy.***

As Null Hypothesis is not rejected,
so no need to do post hoc test Tukey HSD

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

"- State the null and alternate hypotheses - Check the assumptions of the hypothesis test. - Conduct the hypothesis test and compute the p-value Write down conclusions from the test results - In case the implant hardness differs, identify for which pairs it differs Note: 1. Both types of alloys cannot be considered together. You must conduct the analysis separately for the two types of alloys. 2. Even if the assumptions of the test fail, kindly proceed with the test."

State the null and alternate hypotheses

In [77]:

Hypothesis test formulation for Alloy 1

H01: The mean implant hardness is the same for all methods with type 1 alloy.

HA1: Mean implant hardness is different for at least one pair of the method with type 1 alloy.

Hypothesis test formulation for Alloy 2

H01: The mean implant hardness is the same for all methods with type 2 alloy.

HA1: Mean implant hardness is different for at least one pair of the method with type 2 alloy.

Check the assumptions of the hypothesis test.
The results from an ANOVA test are most reliable when the assumptions of normality and equality of variances are satisfied.

For testing of normality, Shapiro-Wilk's test is applied to the response variable.

For equality of variance, Levene test is applied to the response variable.

Test of Normality (Shapiro) for Type 1 Alloy for Method variable

H0 1: the implant hardness of "Method" variable within the "Type 1 Alloy" follows a normal distribution

HA 1:the implant hardness of "Method" variable within the "Type 1 Alloy" does not follow a normal distribution.

#apply shapiro test for hardness of different Method within type 1 Alloy using for loop

Shapiro-Wilk Test static value: 0.9183822870254517 p-value: 0.18198540806770325

Shapiro-Wilk Test static value: 0.9732585549354553 p-value: 0.9030335545539856

Shapiro-Wilk Test static value: 0.9114548563957214 p-value: 0.14254699647426605

In none of the cases, p-value is smaller than level of significance(0.05). **Hence normality assumption is satisfied**

Test of Normality (Shapiro) for Type 2 Alloy for Method variable

H0 2: the implant hardness of "Method" variable within the "Type 2 Alloy" follows a normal distribution

HA 2:the implant hardness of "Method" variable within the "Type 2 Alloy" does not follow a normal distribution.

apply shapiro test for hardness of different Method within type 2 Alloy using for loop

Shapiro-Wilk Test static value: 0.963810384273529 p-value: 0.7582374811172485

Shapiro-Wilk Test static value: 0.755793035030365 p-value: 0.001051110913977027

Shapiro-Wilk Test static value: 0.9021322131156921 p-value: 0.1025901660323143

For one method, p-value is smaller than level of significance(0.05).others are greater than level of significance(0.05). **We will proceed with ANOVA**.

Levene test of equal variance for Type 1 and Type 2 Alloy for Method variable

H0: variances for Type 1 and Type 2 Alloy for Method variables are equal

Ha: At least one variance is different from the rest

- create data frame with alloy type 1 metal implants hardness
- apply levene test for type 1 Alloy with Method variable

levene test static value: 6.52140454403598 ,p value: 0.0034160381460233975

- create data frame with alloy 2 type metal implant
- apply levene test for type 2 Alloy with Method variable

levene test static value: 3.349707184158617 ,p value: 0.04469269939158668

Form above result for both alloy 1 and alloy 2 p value is less than level of significance(0.05), **we can conclude that the variances are not equal**

Conduct the hypothesis test and compute the p-value

Hypothesis test formulation for Alloy 1

H01: The mean implant hardness is the same across different method with type 1 alloy.

HA1: Mean implant hardness is different for at least one pair of the method with type 1 alloy.

- *create data frame with alloy 1 type*
- *create anova table with Method variable*

	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

Table-6-*create anova table with Method variable of Alloy1*

Since p-value is smaller than level of significance(0.05), null hypothesis is rejected. **Mean implant hardness is different for at least one pair of the method with type 1 alloy.**

Hypothesis test formulation for Alloy 2

H01: The mean implant hardness is the same across different Method with type 2 alloy.

HA1: Mean implant hardness is different for at least one pair of the Method with type 2 alloy.

- *create data frame with alloy 2 type*
- *create anova table with Method variable for 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

Table-7-Create *anova table with Method variable of Alloy-2*

As the p-value is much less than the significance level, we can reject the null hypothesis. **Hence, we do have enough statistical significance to conclude that at least one implants hardness is different from the rest at 5% significance level for alloy 2 type.**

Write down conclusions from the test results

However, we don't know which mean is different from the rest or whether all pairs of means are different in both alloy type. Multiple comparison tests are used to test the differences between all pairs of means.

In case the implant hardness differs, identify for which pairs it differs Note

Multiple Comparison test (Tukey HSD)

In order to identify for which Method type mean implants hardness is different from other groups, the null hypothesis is $H0:\mu1=\mu2$ and $\mu1=\mu3$ and $\mu2=\mu3$ against the alternative hypothesis

$Ha:\mu1\neq\mu2$ or $\mu1\neq\mu3$ or $\mu2\neq\mu3$

The pairwise_tukeyhsd() function of Stats models will be used to compute the test statistic and p-value.

- ❖ *import the required function* pairwise_tukeyhsd
- ❖ *perform multiple pairwise comparison (Tukey HSD) for implant hardness of differe nt method*

Multiple Comparison of Means - Tukey HSD, FWER=0.05

==

group1	group2	meandiff	p-adj	lower	upper	reject
1.0	2.0	10.4333	0.9415	-64.7584	85.6251	False
1.0	3.0	-166.8	0.0	-241.9917	-91.6083	True
2.0	3.0	-177.2333	0.0	-252.4251	-102.0416	True

Table-8-multiple comparison

Insights

- ❖ #As the p-values (refer to the p-adj column) for comparing the mean implants hardness for method pair 1-3 and 2-3 is less than the significance level, the null hypothesis of equality of all population means can be rejected.
- ❖ **Thus, we can say that the mean implants hardness for method 1 and 2 is similar but hardness for method type 3 is significantly different from 1 and 2 Method Type**.

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

"- Create Interaction Plot - Inferences from the plot Note: Both types of alloys cannot be considered together. You must conduct the analysis separately for the two types of alloys."

Create Interaction Plot interaction plot for Alloy-1 ❖ import the interaction plot function ❖ create data frame with alloy type 1.

❖ plot interaction plot for alloy 1 with implant hardness(response) ,Methods ,Dentist variable

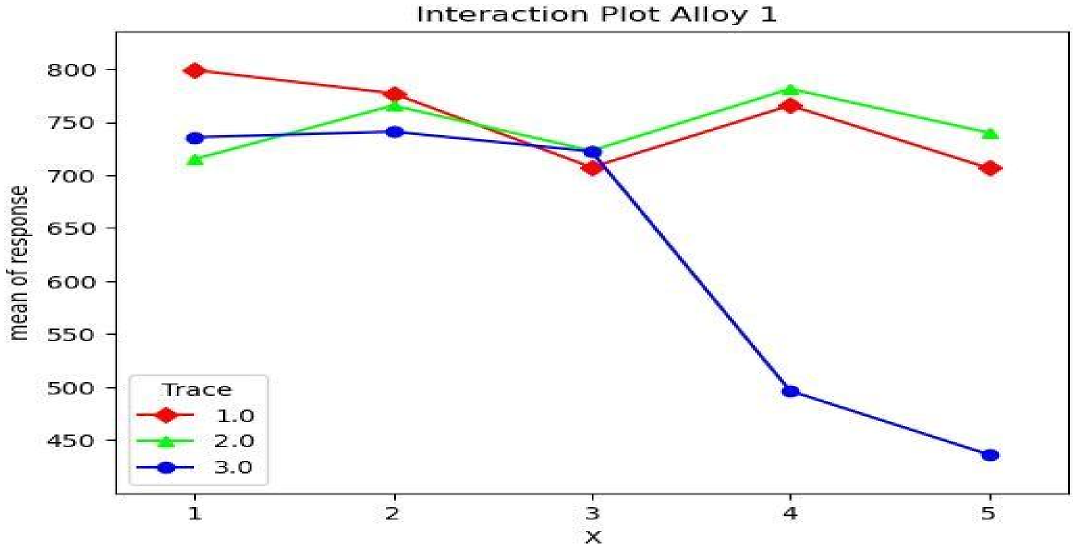

Figure-5-Interaction Plot Alloy 1

We can clearly say that mean hardness of dental implant is not same when different Dentists are using different Methods in Alloy 1. This interaction is very significant here.

Interaction plot for Alloy-2

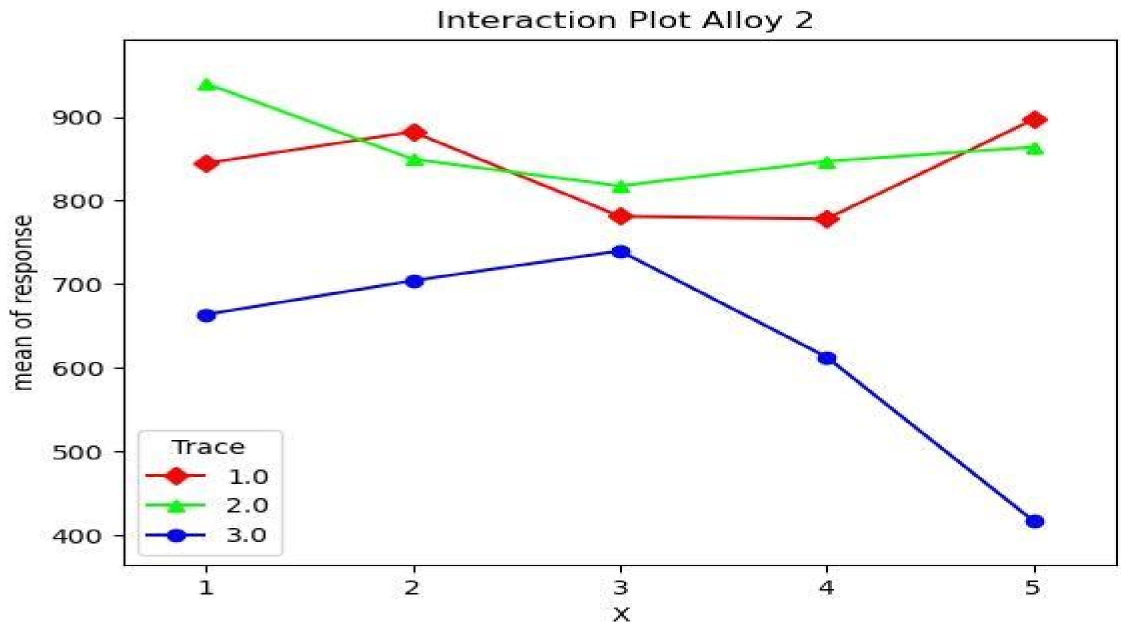

Figure-6-Interaction Plot Alloy 2

We can clearly say that mean hardness of dental implant is not same when different Dentists are using different Methods in Alloy 2. This interaction is very significant here.

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

"- State the null and alternate hypotheses - Check the assumptions of the hypothesis test. - Conduct the hypothesis test and compute the p-value Write down conclusions from the test results - Identify which dentists and methods combinations are different, and which interaction levels are different. Note: 1. Both types of alloys cannot be considered together. You must conduct the analysis separately for the two types of alloys. 2. Even if the assumptions of the test fail, kindly proceed with the test."

State the null and alternate hypotheses

Hypothesis test formulation for Alloy 1

for Dentist variable

H0: The mean implant hardness is same across different Dentists with type 1 Alloy.

HA: Mean implant hardness is different for at least one of the Dentist with type 1 Alloy.

for Method variable

H0: The mean implant hardness is same across different Methods with type 1 Alloy.

HA: Mean implant hardness is different for at least one of the Method type with type 1 Alloy.

for both Dentist and Method variables

H0: There is no interaction between Dentist and Method types with type 1 Alloy.

HA: There is interaction between Dentist and Method types with type 1 Alloy

Hypothesis test formulation for Alloy 2 for Dentist variable

H0: The mean implant hardness is same across different Dentists with type 2 Alloy.

HA: Mean implant hardness is different for at least one of the Dentist with type 2 Alloy.

for Method variable

H0: The mean implant hardness is same across different Methods with type 2 Alloy.

HA: Mean implant hardness is different for at least one of the Method type with type 2 Alloy.

for both Dentist and Method variables

H0: There is no interaction between Dentist and Method types with type 1 Alloy.

HA: There is interaction between Dentist and Method types with type 1 Alloy

Check the assumptions of the hypothesis test.

The results from an ANOVA test are most reliable when the assumptions of normality and equality of variances are satisfied.

For testing of normality, Shapiro-Wilk's test is applied to the response variable.

For equality of variance, Levene test is applied to the response variable.

Test of Normality (Shapiro) for to assess the normality of the hardness of implants data for alloy 1 based on the interaction between dentists and methods.

Null Hypothesis (H0): The hardness of implants data for alloy 1, considering the interaction between dentists and methods, follows a normal distribution.

Alternative Hypothesis (Ha): The hardness of implants data for alloy 1, considering the interaction between dentists and methods, does not follow a normal distribution.

❖ apply Shapiro test for Method 1 ,2,3 with different Dentists of Alloy 1

type method 1,with different Dentist

p_value: -9.106917104872991e-07
p_value: 0.17733535170555115
p_value: 0.12336116284132004
p_value: 0.7538362145423889
p_value: 0.9351651668548584

method 2,with different Dentist
p_value: 0.5291318893432617
p_value: 0.47633662819862366
p_value: 0.6724511384963989
p_value: 0.8395751118659973
p_value: 0.7144943475723267

method 3,with different Dentist
p_value: 0.75013267993927
p_value: 0.482163667678833
p_value: -9.106917104872991e-07
p_value: 0.9736139178276062
p_value: 0.3732281029224396

2 values are only less than 0.05 ,other p values are greater than 0.05,most samples follows The hardness of implants data for alloy 1, considering the interaction between dentists and methods, follows a normal distribution.

Test of Normality (Shapiro) forTo assess the normality of the hardness of implants data for alloy 2 based on the interaction between dentists and methods,

Null Hypothesis (H0): The hardness of implants data for alloy 2, considering the interaction between dentists and methods, follows a normal distribution.

Alternative Hypothesis (Ha): The hardness of implants data for alloy 2, considering the interaction between dentists and methods, does not follow a normal distribution.

❖ apply Shapiro test for Method 1,2,3 with different Dentists of Alloy 2 type

❖

method 1,with different Dentist
p_value: 0.723876953125
p_value: 0.9774916172027588
p_value: 0.532307505607605
p_value: 0.8160430788993835
p_value: 0.6833236217498779

method 2,with different Dentist
p_value: 0.219557985663414
p_value: 0.4166799485683441
p_value: 0.6806928515434265
p_value: 0.383916437625885
p_value: 0.1752912998199463

method 3,with different Dentist
p_value: 0.15032446384429932
p_value: 0.6102096438407898
p_value: 0.4384445548057556
p_value: 0.35447922348976135
p_value: 0.8135352730751038

all p-values is greater than 0.05,fail to the rejection of null hypothesis,**it mean The hardness of implants data for alloy 2, considering the interaction between dentists and methods, follows a normal distribution.**

Levene test of equal variance for Type 1 and Type 2 Alloy for Method variable

H0: variances for Type 1 and Type 2 Alloy for Method and dentists variables are equal

Ha: At least one variance is different from the rest

❖ *apply Levene test for Method 1,2,3 with different Dentists of Alloy 1 type*

m

levene test statistic value: 0.5529474397444584 ,p value: 0.701672174101884

e

thod 1 for different dentist method 2

for different dentist

levene test static value: 0.6201949738770031 ,p value: 0.6583876924956382

method 3 for different dentist

levene test static value: 1.3678197608692764 ,p value: 0.31229654205500973

❖ apply Levene test for Method 1,2,3 with different Dentists of Alloy 2 type

method 1 for different dentist

levene test static value: 0.8621300400689107 ,p value: 0.518759139034454

4

method 2 for different dentist

levene test static value: 0.6201949738770031 ,p value: 0.6583876924956382

method 3 for different dentist

levene test static value: 1.3678197608692764 ,p value: 0.31229654205500973

p values for alloy 1 and alloy 2 are greater than 0.05,fail to reject the null hypothesis,it means the variances for Type 1 and Type 2 Alloy for Method and dentists variables are equal then go to the anova test.

Hypothesis test formulation for Alloy 1

for different Dentists

H0: The mean implant hardness is same across different Dentists with type 1 Alloy.

HA: Mean implant hardness is different for at least one of the Dentist with type 1 Alloy.

for different Methods

H0: The mean implant hardness is same across different Methods with type 1 Alloy.

HA: Mean implant hardness is different for at least one of the Method type with type 1 Alloy.

for interaction b/w Dentists and Method variables

H0: There is no interaction between Dentist and Method types with type 1 Alloy.
HA:There is interaction between Dentist and Method types with type 1 Alloy

create data frame with Alloy 1 type
create the Anova table with function Dentist and Method variables

	Df	sum_sq	mean_sq	F	PR(>F)
C(Dentist)	4.0	106683.688889	26670.922222	2.591255	0.051875
C(Method)	2.0	148472.177778	74236.088889	7.212522	0.002211
Residual	38.0	391121.377778	10292.667836	NaN	NaN

Table-9 – ***Anova table with function Dentist and Method variables of Alloy1***

Interaction b/w Dentists and Method variables for Alloy 1
create the anova table with function Dentist and Method variables and interaction b/w this 2 variables(using Two Way ANOVA)

	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-10-Anova table with function Dentist and method variable &interaction b/w this 2 variables of Alloy1

- *There is a statistically significant interaction effect between Dentist and Method on implant hardness, as the p-value for the interaction effect is less than the significance level (0.006793).
- *The hardness of implants significantly varies depending on the method used (Main Effect of Method), as indicated by the very small p-value (0.000284).

- *There is a statistically significant difference in implant hardness among different dentists (Main Effect of Dentist), as the p-value is less than the significance level (0.011484).

Therefore,In Alloy 1 the variation in implant hardness is influenced by both the specific dentist and the method used, and there is a significant interaction effect between these two factors.

Hypothesis test formulation for Alloy 2

for different Dentists

H0: The mean implant hardness is same across different Dentists with type 2 Alloy.
HA: Mean implant hardness is different for at least one of the Dentist with type 2 Alloy.

for different Methods

H0: The mean implant hardness is same across different Methods with type 2 Alloy.

HA: Mean implant hardness is different for at least one of the Method type with type 2 Alloy.

for interaction b/w Dentists and Method variables

H0: There is no interaction between Dentist and Method types with type 2 Alloy.

HA: There is interaction between Dentist and Method types with type 2 Alloy

- *create data frame with alloy type 2*
- *create the Anova table with function Dentist and Method variables*

	Df	sum_sq	mean_sq	F	PR(>F)

C(Dentist)	4.0	56797.911111	14199.477778	0.926215	0.458933
C(Method)	2.0	499640.400000	249820.200000	16.295479	0.000008
Residual	38.0	582564.488889	15330.644444	NaN	NaN

Table-11-Anova table with function Dentist and Method variables of Alloy2

Interaction b/w Dentists and Method variables for Alloy 2

Create the Anova table with function Dentist and Method variables and interaction b/w this 2 variables

	Df	sum_sq	mean_sq	F	PR(>F)
C(Dentist)	4.0	56797.911111	14199.477778	1.106152	1.106152
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-12-Anova table with function Dentist and Method variables **&interaction b/w this 2 variables of Alloy2**

- There is no statistically significant interaction effect between Dentist and Method on implant hardness, as the p-value for the interaction effect is greater than the significance level ,(fail to rejection of null hypothesis).

- *The hardness of implants significantly varies depending on the method used (Main Effect of Method), as indicated by the very small p-value (0.000004).

- *There is no statistically significant difference in implant hardness among different dentists (Main Effect of Dentist), as the p-value is greater than the significance level (0.371833).

Therefore,In Alloy 2 the variation in implant hardness is mainly associated with the method used, while the specific dentist does not significantly affect the hardness, and there is no strong interaction effect between the two factors.