INFERENTIAL STATSTICS PROJECT BUSINESS REPORT

TITLE:

Statistical Analysis and Insights for Healthcare, Sports, Quality Assurance, and Manufacturing

Subtitle:

A Comprehensive Study on Player Injuries, Packaging Strength, Stone Hardness, and Dental Implant Reliability

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5.Recommondations:

1.Problem 1 :

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.

This report presents a statistical analysis to evaluate the probability of injuries among players, the probability of players occupying specific positions, and the likelihood of various conditions related to player positions and injuries. The findings are based on data regarding a total of 235 players.

	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**

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

To determine the probability that a randomly selected player would suffer an injury, we use the following formula:

- Probability (P)= Total number of players/Number of players who suffered an injury
- Total Number of Players: 235
- Number of Players Who Suffered an Injury: 145
- P = 145/235 = 0.61

Thus, there is approximately a **61.7**% probability that any randomly chosen player will suffer an injury.

1.2 Probability of a Player Being a Forward or Winger?

Next, we calculate the probability that a player is either a forward or a winger:

- P = (no of forward player + no of winger player) /Total no of player
- From data provided
- total no of player is forward = 94
- total no of player is winger = 29
- total no of forward and winger player = 94+29 = 123
- Total Number of Players: 235
- p = 123/235

Hence, there is a **52.3%** probability that a player is a forward or a winger.

1.3 Probability that a Player Plays in a Striker Position and Has a Foot Injury?

- We also evaluate the probability that a player plays in a striker position and has a foot injury:
- P(Striker and Foot Injury) = {Number of Strikers with Foot Injury) /(Total Number of Players)
- From data provided
- no of player who plays in striker position got injured is 45
- total no of players = 235
- p = 45/235 = 0.1914

Thereby, there is a 19.1% 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?

Finally, we determine the probability that a randomly selected injured player is a striker:

- From the data provided:
- Total Number of Injured Players: 145
- Number of Injured Strikers: 45
- p = 45/145 = 0.31

Thus, there is a 31.0% probability that an injured player is a striker.

1.5 Conclusion:

The statistical analysis reveals:

- A 61.7% probability of a randomly chosen player suffering an injury.
- A 52.3% probability of a player being a forward or a winger.
- A 19.1% probability that a randomly chosen player plays in a striker position and has a foot injury.
- A 31.0% probability that a randomly injured player is a striker.

These insights can guide future strategic decisions in player training, injury prevention, and position management, optimizing overall team performance.

This report utilizes Python libraries for statistical analysis and data visualization to address the key problems faced by Zingaro Stone Printing. The following libraries are used:

- Pandas: Used for data manipulation and analysis.
- NumPy: Provides support for large, multi-dimensional arrays and matrices, along with a collection of mathematical functions.
- Matplotlib: A 2D plotting library used for creating static, animated, and interactive visualizations.
- Seaborn: A statistical data visualization library based on Matplotlib, providing a high-level interface for drawing attractive and informative statistical graphics.
- SciPy: Used for scientific and technical computing, including modules for optimization, integration, interpolation, eigenvalue problems, and more.
- Statsmodels: Provides classes and functions for the estimation of various statistical models, as well as for conducting statistical tests.

2.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 a 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

2.1 Introduction:

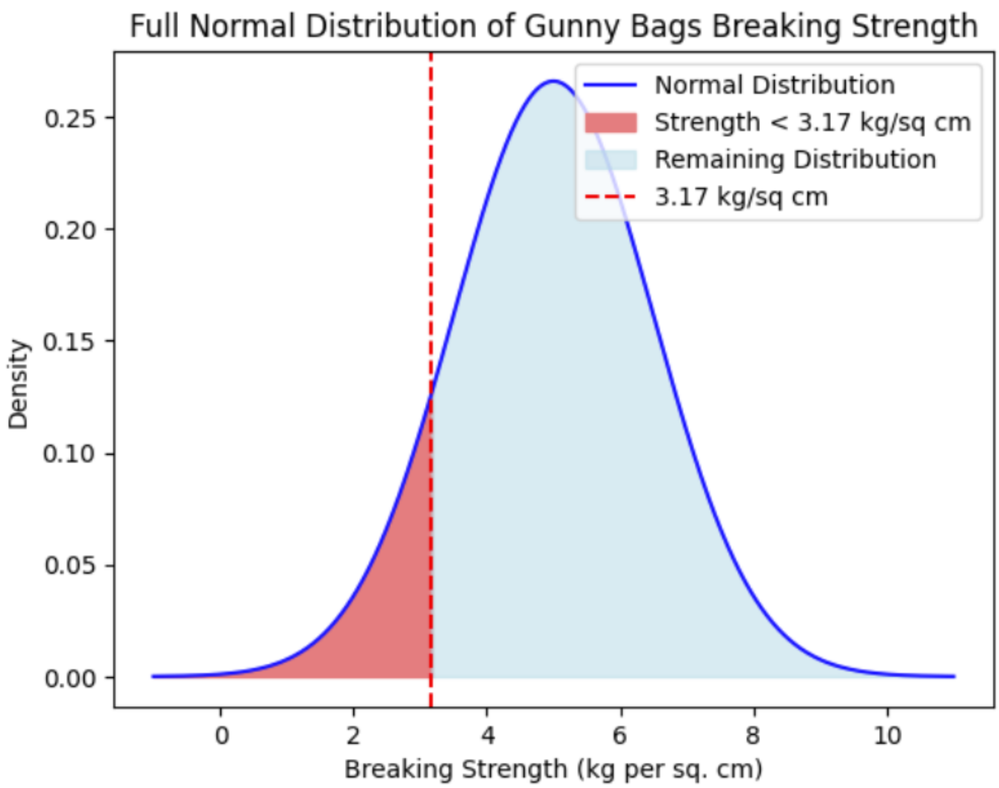
This report provides a statistical analysis of the breaking strength of gunny bags used for packaging cement. The breaking strength is normally distributed with a mean of 5 kg per sq. centimetre and a standard deviation of 1.5 kg per sq. centimetre. The analysis aims to understand the proportion of gunny bags falling within specific breaking strength ranges to assess potential wastage or pilferage within the supply chain.

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

- The quality team is interested in the proportion of gunny bags having a breaking strength of less than 3.17 kg per sq. cm. Using the properties of a normal distribution, we can determine this proportion accurately. The cumulative distribution function (CDF) provides the probability that a normally distributed random variable falls below a given value.
- Mean ((\mu)): 5 kg per sq. cm
- Standard Deviation ((\sigma)): 1.5 kg per sq. cm
- Value of Interest (X): 3.17 kg per sq. cm
- To determine the proportion of gunny bags with a breaking strength less than 3.17 kg per sq. cm, we calculate the cumulative probability of the Z-score corresponding to X = 3.17. Using statistical tools, the cumulative probability density function (CDF) . we use norm.cdf
- INTERPRETATION:
  The cumulative distribution function value indicates that approximately 11% of the gunny bags have a breaking strength of less than 3.17 kg per sq. cm. This suggests that these bags are likely to fail under stress conditions below this threshold

This analysis provides critical insights for the quality assurance team. The company can use this information to identify potential quality control issues and take necessary steps to prevent wastage or pilferage. Ensuring that breaking strengths meet minimum standards is essential for maintaining the integrity of the packaging and preventing losses in the supply chain.

A graph showcasing the normal distribution curve with the highlighted area representing the proportion of gunny bags with a breaking strength less than 3.17 kg per sq. cm can be seen below:



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

- The quality team aims to determine the proportion of gunny bags with a breaking strength of at least 3.6 kg per sq. cm.
- Parameters:

Mean ((\mu)): 5 kg per sq. cm

Standard Deviation ((\sigma)): 1.5 kg per sq. cm

Threshold Value (X): 3.6 kg per sq. cm

By using the cumulative distribution function (CDF) for a normal distribution, we can determine the proportion of gunny bags with breaking strengths of at least 3.6 kg per sq. cm.

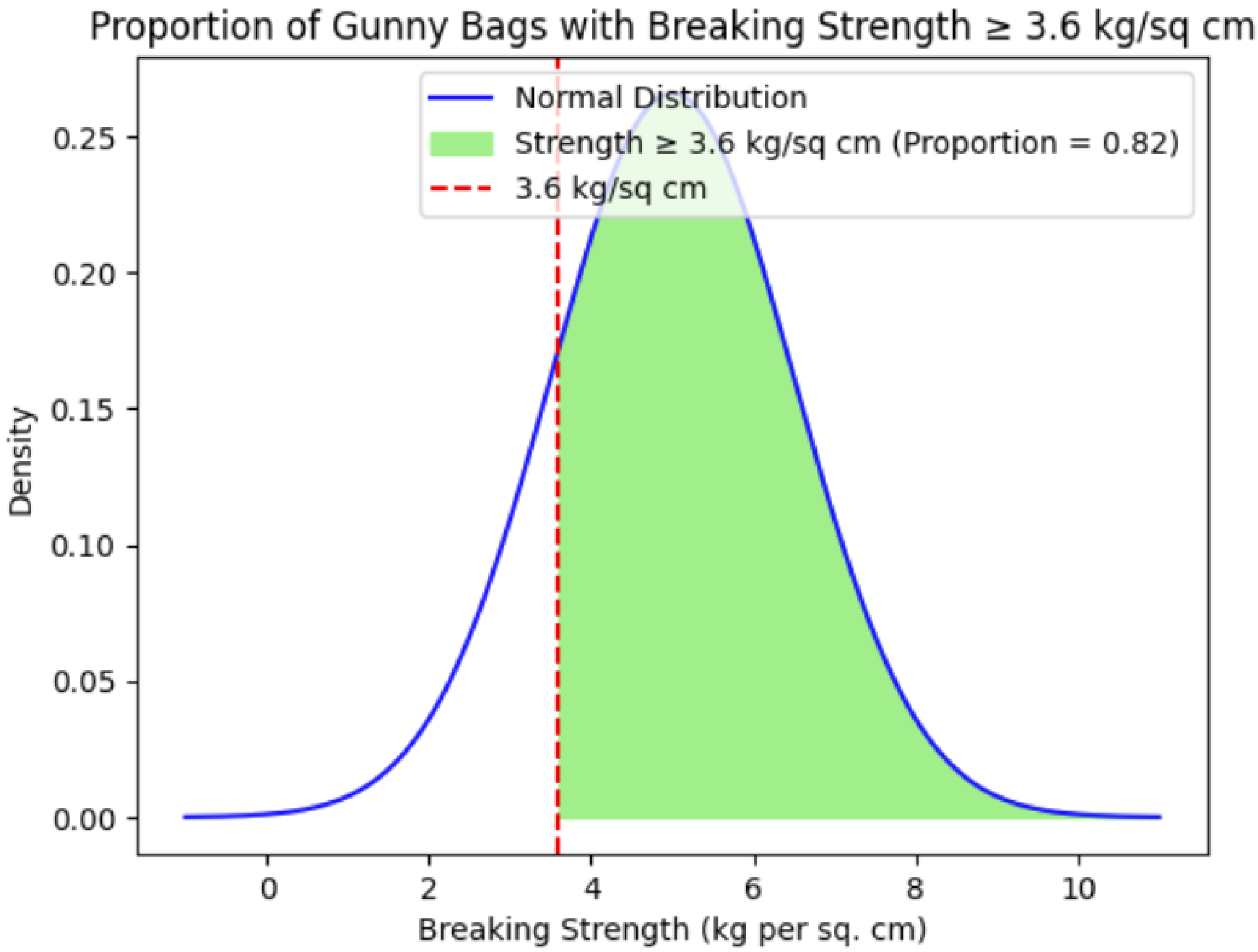
- Calculation:

To find the required proportion, we first calculate the cumulative probability for a breaking strength of less than 3.6 kg per sq. cm. We then subtract this probability from 1 to obtain the probability of having a breaking strength of at least 3.6 kg per sq. cm.

- Interpretation:

The calculation indicates that approximately 82% of the gunny bags have a breaking strength of at least 3.6 kg per sq. cm. This high proportion suggests that the majority of gunny bags used for packaging are robust enough to handle higher stress levels.

The graph below illustrates the normal distribution curve with the shaded area in green representing the proportion of gunny bags with a breaking strength of at least 3.6 kg per sq. cm:



2.4Proportion of Gunny Bags with Breaking Strength Between 5 and 5.5 kg per sq. cm

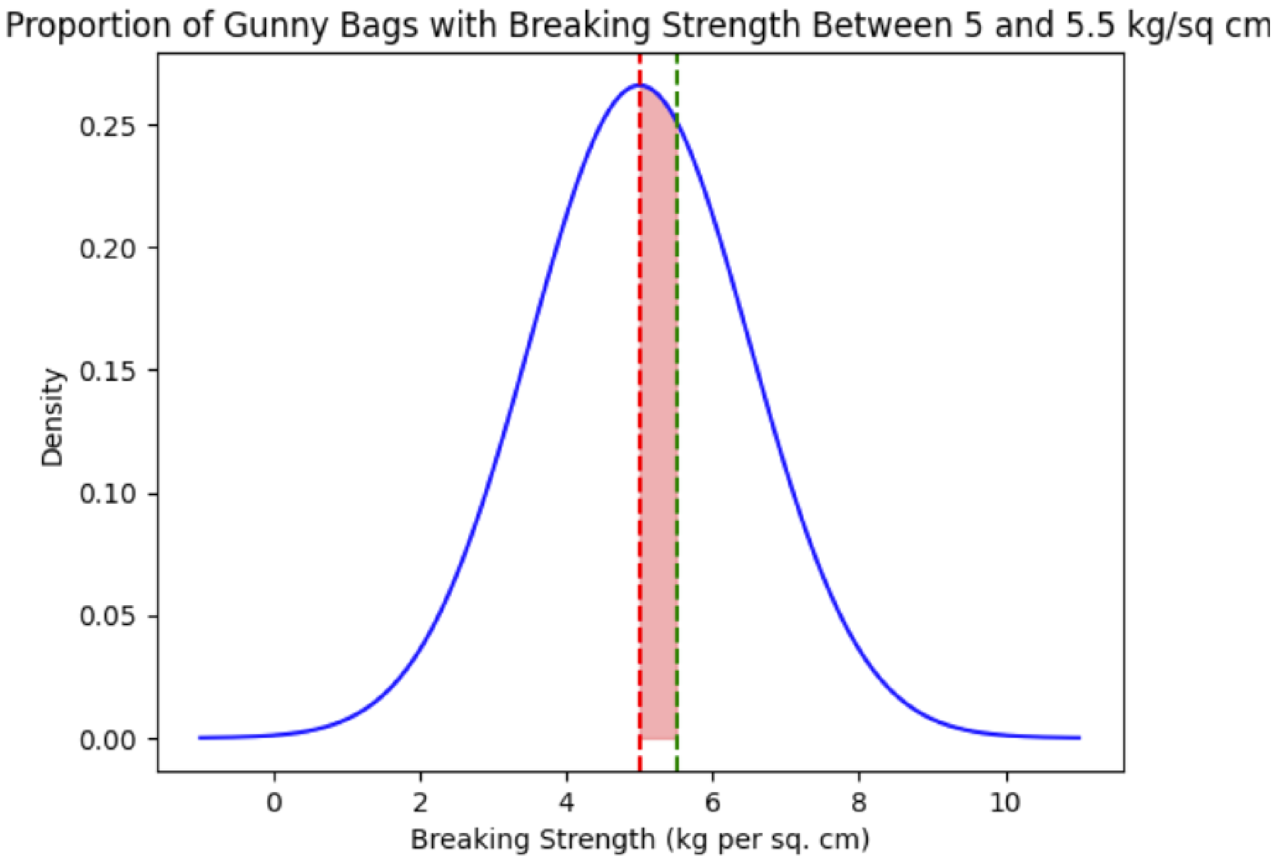
The quality team wants to determine the proportion of gunny bags with a breaking strength between 5 and 5.5 kg per sq. cm.

- Parameters:
- Mean : 5 kg per sq. cm
- Standard Deviation : 1.5 kg per sq. cm
- Lower Bound : 5 kg per sq. cm
- Upper Bound : 5.5 kg per sq. cm

Calculation: To find the proportion of gunny bags within this range, we calculate the cumulative probability for both the lower and the upper bounds. The proportion is the difference between these two cumulative probabilities. We use norm.cdf function to find the cumulative frequency

- Interpretation:
  The calculation reveals that approximately **13%** of the gunny bags have a breaking strength between 5 and 5.5 kg per sq. cm. This proportion indicates a subset of the gunny bags that are close to the mean strength value, representing a specific range of strength that the quality team might want to scrutinize further.

  The graph below illustrates the normal distribution curve with the shaded area in peach representing the proportion of gunny bags with a breaking strength between 5 and 5.5 kg per sq. cm



2.5 Proportion of Gunny Bags with Breaking Strength NOT Between 3 and 7.5 kg per sq. cm

- Parameters:
- Mean : 5 kg per sq. cm
- Standard Deviation : 1.5 kg per sq. cm
- Lower Bound : 3 kg per sq. cm
- Upper Bound : 7.5 kg per sq. cm
- Calculation:

Probability of Breaking Strength Less Than 3 kg per sq. cm:

The cumulative distribution function (CDF) provides the probability that a normally distributed random variable falls below a given value.

For X = 3 kg per sq. cm, the CDF value is found to be approximately 0.0918.

Probability of Breaking Strength Less Than 7.5 kg per sq. cm:

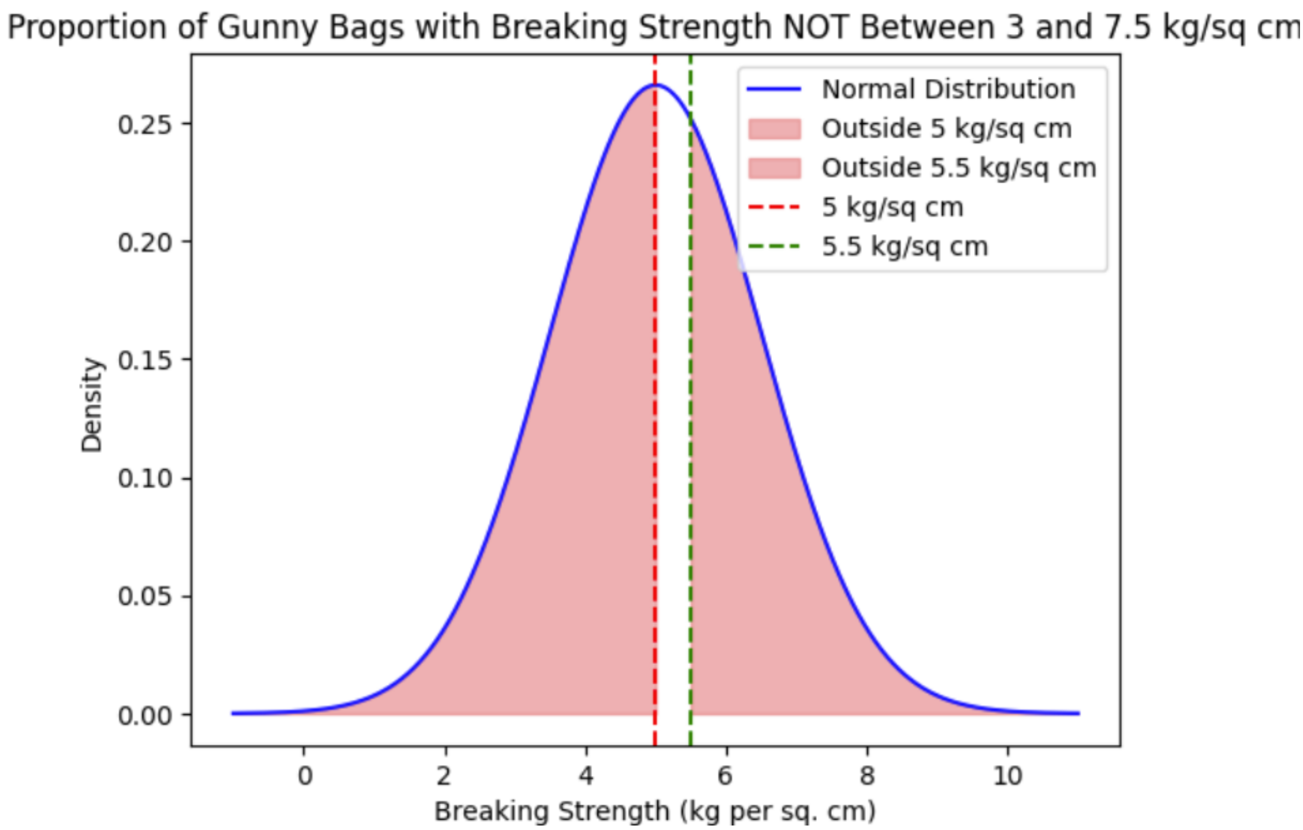
For X = 7.5 kg per sq. cm, the CDF value is found to be approximately 0.9525.

Probability of Breaking Strength Between 3 and 7.5 kg per sq. cm is 0.86

Now to find the probability of breaking strength not between 3lg and 7.5 is 1-0.86 is approximately 1.4

Interpretation:

The calculation indicates that approximately 14% of the gunny bags have a breaking strength that does not fall between 3 and 7.5 kg per sq. cm. This suggests that these bags either have lower strength or exceedingly high strength, potentially indicating variability in material quality or manufacturing inconsistencies.



Overall Conclusion:

- 1% of gunny bags have a breaking strength of less than 3.17 kg per sq. cm.

- This analysis provides critical insights for the quality assurance team. The company can use this information to identify potential quality control issues and take necessary steps to prevent wastage
- 82% of gunny bags have a breaking strength of at least 3.6 kg per sq. cm.
- This result is critical for the quality assurance team, as it validates that a significant majority of the packaging materials possess adequate strength, reducing the likelihood of damage or failure during handling and transport.
- 13% of gunny bags have a breaking strength between 5 and 5.5 kg per sq. cm.
- This information is vital for the quality assurance team to ensure that the majority of the packaging materials are within acceptable strength limits. Monitoring this subset of gunny bags helps in maintaining product integrity and can be crucial in minimizing losses throughout the supply chain.
- 14% of gunny bags have a breaking strength that is not between 3 and 7.5 kg per sq. cm.
- This information is critical for the quality assurance team to address quality control measures effectively. Understanding the proportion of gunny bags that fall outside the optimal strength range can help in identifying potential weaknesses in manufacturing processes, leading to improved product quality and reduced losses in the supply chain.

3.1.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

3.2 Exploratory Data Analysis (EDA)

- To begin the analysis, the dataset is read using the pd.read_csv function from the Pandas library. Below are the key observations from the Exploratory Data Analysis:
- Dataset Dimensions: the dataset consists of 75 rows and 2 columns.
- Missing Values: There are no missing values in the dataset, ensuring complete data integrity for analysis.
- Summary Statistics:

	Unpolished	Treated and Polished
count	75.000000	75.000000
mean	134.110527	147.788117
std	33.041804	15.587355
min	48.406838	107.524167
25%	115.329753	138.268300
50%	135.597121	145.721322
75%	158.215098	157.373318
max	200.161313	192.272856

- Unpolished Stones:
  Average Hardness Index: 134.11
  Standard Deviation: 33.04
- Polished Stones:
  Average Hardness Index: 147
  Standard Deviation: 15.58

These initial findings offer an overview of the dataset, providing a foundation for further statistical analysis to address Zingaro Stone Printing's concerns.

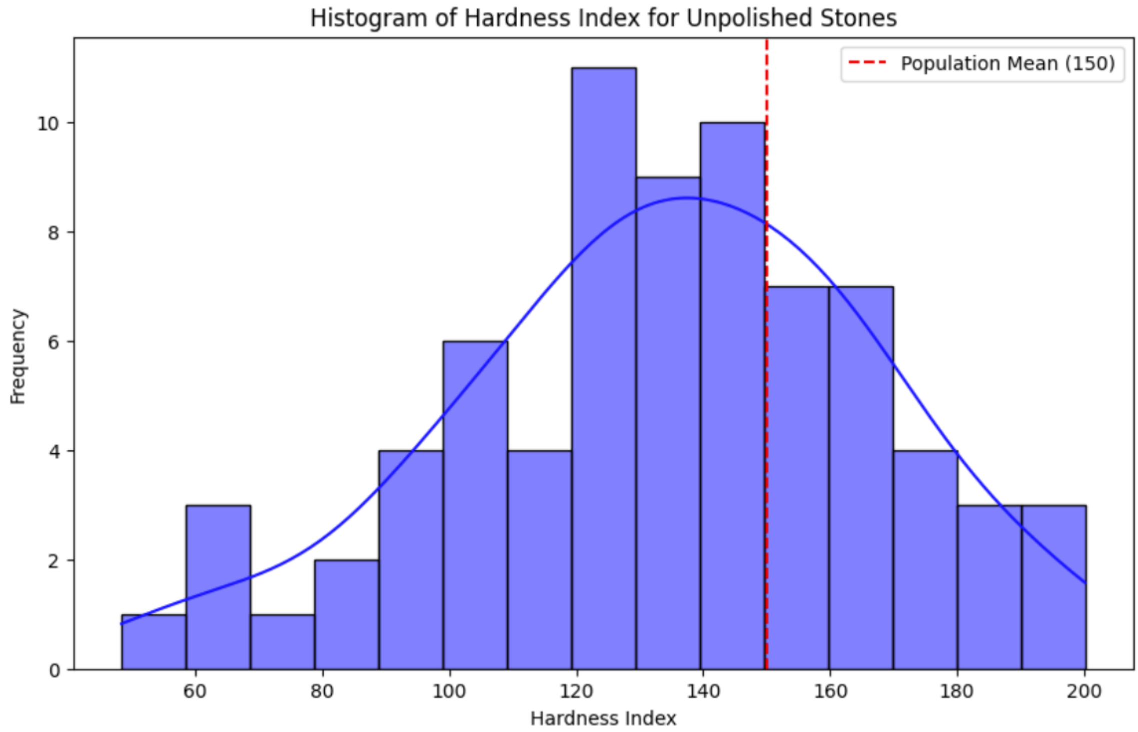
3.3 Objectives:

- Determine if the unpolished stones are suitable for printing by testing if their Brinell's hardness index meets the required minimum of 150.
- Compare the mean hardness of polished and unpolished stones to assess if there is a significant difference.

3.4 Determine if the unpolished stones are suitable for printing by testing if their Brinell's hardness index meets the required minimum of 150

- Stating the hypothesis null and alternative:
- **Null hypothesis** = the unpolished stones may not be suitable that is the hardness index is less than 150
- **Alternate hypothesis** = the unpolished stones may be suitable that is the hardness index is at least 150 or greater
- H_0 : mu < 150

- Ha : mu > 150
- Test Details: Since the standard deviation of population is unknown, we can go for one sample t-test
- Test Type: One-sample t-test (right-tailed)
- Level of Significance: 5%
- WE will find the p-value using ttest_samp1 function the p-value is approximately 1
- **Conclusion:**
- Given that the test produced a p-value of approximately 1, which is significantly greater than 0.05, we fail to reject the null hypothesis. This indicates that there is not enough evidence to conclude that the unpolished stones have a hardness index of at least 150. Hence, these stones are likely unsuitable for printing.
- The graph below shows the hardness index of polished and unpolished stones



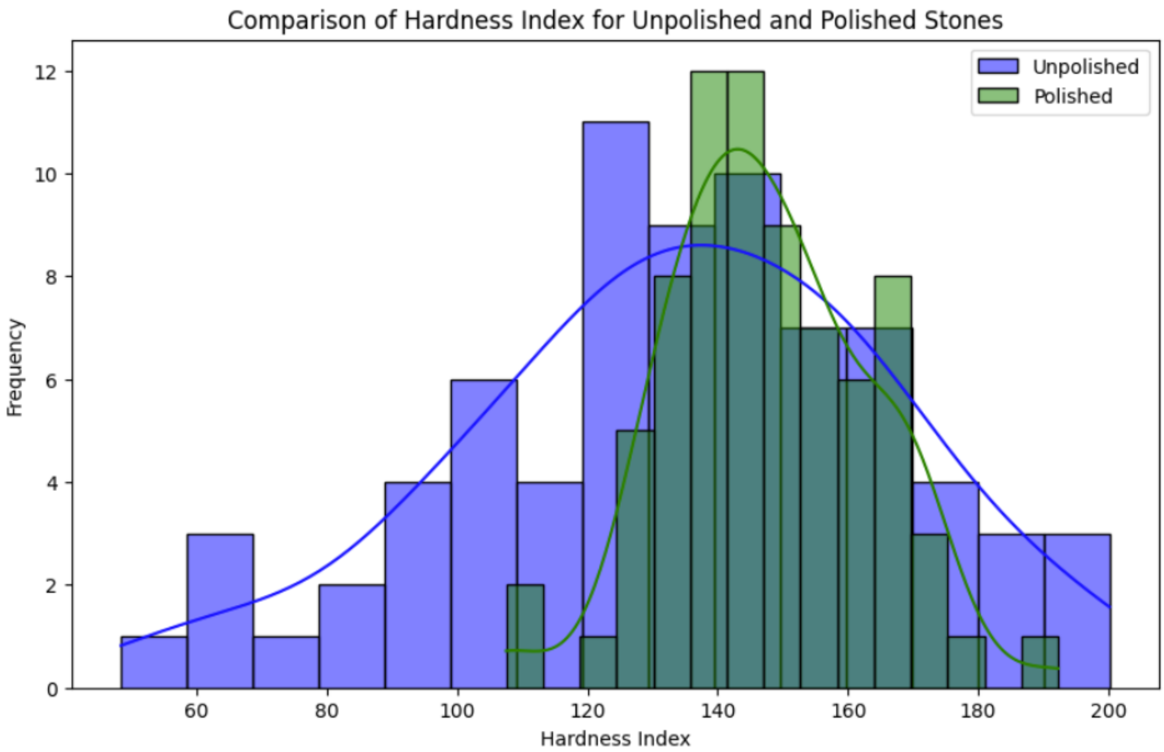
3.5. Compare the mean hardness of polished and unpolished stones to assess if there is a significant difference.

forming hypothesis :

- Null hypothesis - the mean hardness of polished and unpolished stones are same
- Alternate hypothesis - The mean hypothesis of polished and unpolished are not same
- H_0 : mu1 = mu2
- Ha : mu != mu2
- this is Cleary test for 2 means and it is two tailed test

- the average hardness of index of unpolished stones is 134.11 and that of treated and polished is 147
- the standard deviation of unpolished stone is 33.04 and that of polished stone is 15.58 since the standard deviations are different we opt here for **Test for equality of means unequal and unknown std dev that / Two independent sample T-Test for equality of means**
- we use ttest_ind function to get the p value, the p value is 0.0015
- Conclusion:
- Since p-value (0.001588) is less than 0.05, reject the null hypothesis. There is sufficient evidence to conclude that the mean hardness of polished and unpolished stones is different.

Below is the graph that shows mean comparison between polished and unpolished stones



Summary:

The unpolished stones are not suitable for printing as their hardness index does not meet the required threshold of 150.There is a significant difference between the mean hardness indices of polished and unpolished stones, with polished stones having a higher mean hardness.

Recommendations:

Given these insights, Zingaro Stone Printing should focus on using polished stones for their printing services or explore methods to enhance the hardness index of unpolished stones to meet the optimal hardness requirement. This approach will ensure better quality and durability of printed images or patterns.

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 favourite method. The response is the variable of interest

Before diving into the detailed analysis of how the hardness of dental implants varies based on different dentists and methods, we performed Exploratory Data Analysis (EDA) to understand the dataset's structure and characteristics. This section provides a summary of our findings from the EDA.

- Data set Dimension: There are 90 rows and 5 columns in the dataset
- Missing values: There are no missing values in the dataset
- Data Type: The datatype of all the columns is integer

- Summary Statistics:

	Dentist	Method	Alloy	Temp	Response
count	90.000000	90.000000	90.000000	90.000000	90.000000
mean	3.000000	2.000000	1.500000	1600.000000	741.777778
std	1.422136	0.821071	0.502801	82.107083	145.767845
min	1.000000	1.000000	1.000000	1500.000000	289.000000
25%	2.000000	1.000000	1.000000	1500.000000	698.000000
50%	3.000000	2.000000	1.500000	1600.000000	767.000000
75%	4.000000	3.000000	2.000000	1700.000000	824.000000
max	5.000000	3.000000	2.000000	1700.000000	1115.000000

- The dataset is evenly distributed with respect to Dentists, Methods, and Alloys.
- Temperature values range from 1500 to 1700, with a mean centered at 1600.
- Response values (implant hardness) range broadly from 289 to 1115, with an average of 741.78.

- The standard deviation values indicate variability within the dataset. The hardness response has a relatively high standard deviation (145.77), reflecting considerable variance among the hardness values.

- Methodology : (for all the questions)
  To address these issues, we conduct separate analyses for two distinct types of alloys used in implants. The steps involved in the hypothesis testing process include:
- Stating the Hypotheses:
  Null Hypothesis (H_0):
  Alternative Hypothesis (Ha):
- Checking the Assumptions:

1. Independence: Samples should be independent.
2. Normality: Hardness data for each group should be approximately normally distributed, checked using the Shapiro-Wilk test.
3. Homogeneity of Variances: The variances should be roughly equal across groups, tested using Levene's test.

- Conducting the Hypothesis Test:

Analysis of Variance (ANOVA) is used to determine if there are statistically significant differences in means across groups.

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

We should analyse differently for alloy 1 and alloy 2

- Alloy 1:
- Hypotheses:
- H_0: The mean hardness of implants is the same for all dentists.
- Ha: At least one dentist's mean implant hardness is different from the others.
- Assumptions:
  1. Normality: The Shapiro-Wilk test confirmed normal distribution (p-value = 0.081).
  2. Homogeneity of Variances: Levene's test failed (p-value >0.05), (p=0.25) Result: Fail to reject the null hypothesis, meaning variances are approximately equal across groups.
- Anova test is used because assumptions are satisfied .one-way anova
- The p-value (0.116567) is greater than the common significance level of 0.05. Therefore, you fail to reject the null hypothesis. This suggests that there is not enough evidence to conclude that there are significant differences in the means of the response variable across the different dentists
- Similarly for Alloy 2
- Hypothesis is same as alloy 1
- Assumptions:
  3. Normality: The Shapiro-Wilk test confirmed normal distribution (p-value = 0.338).
  4. Homogeneity of Variances: Levene's test failed (p-value >0.05), (p=0.23) Result: Fail to reject the null hypothesis, meaning variances are approximately equal across groups.
- Anova test is used because assumptions are satisfied .one-way anova
- The p-value is 0.718031. This value is much higher than the common significance level of 0.05. Therefore, you fail to reject the null hypothesis.
- **Conclusion**

The findings from the ANOVA tests for both Alloy 1 and Alloy 2 support the null hypothesis that the mean hardness of implants does not significantly differ among the dentists. This consistency is valuable from a quality control perspective, indicating that dentist-specific factors may not be a significant source of variability in implant hardness.

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

Alloy 1:

- Hypotheses:
- H_0: The mean hardness of implants is the same across all methods.
- Ha: At least one method’s mean hardness is different from the others.
- Assumptions:
  1. Normality: The Shapiro-Wilk test confirmed normal distribution (p-value = 0.1425).
  2. Homogeneity of Variances: Levene’s test failed (p-value < 0.05), indicating unequal variances, but analysis continued as per instructions.
- Result:
- ANOVA results showed a significant p-value of 0.0042, rejecting the null hypothesis. This indicates significant differences in mean implant hardness across different methods for Alloy

Similarly for Alloy 2:

- Hypotheses:
- H_0: The mean hardness of implants is the same across all methods.
- Ha: At least one method’s mean hardness is different from the others.
- Assumptions:
  3. Normality: The Shapiro-Wilk test confirmed normal distribution (p-value = 0.10).
  4. Homogeneity of Variances: Levene’s test failed (p-value < 0.05),p = 0.04 indicating unequal variances, but analysis continued as per instructions.
- Result:
- Anova result shows that p-value of 0.000005 is extremely small, indicating very strong evidence against the null hypothesis. This suggests that at least one method's mean 'Response' is significantly different from the others
- **Conclusion**

For both Alloy 1 and Alloy 2, the ANOVA results suggest that the mean hardness of implants significantly varies depending on the methods used. This means that for both alloys, at least one method's mean hardness is significantly different from the others, and the null hypothesis—that the mean hardness is the same across all methods—is rejected in both cases.

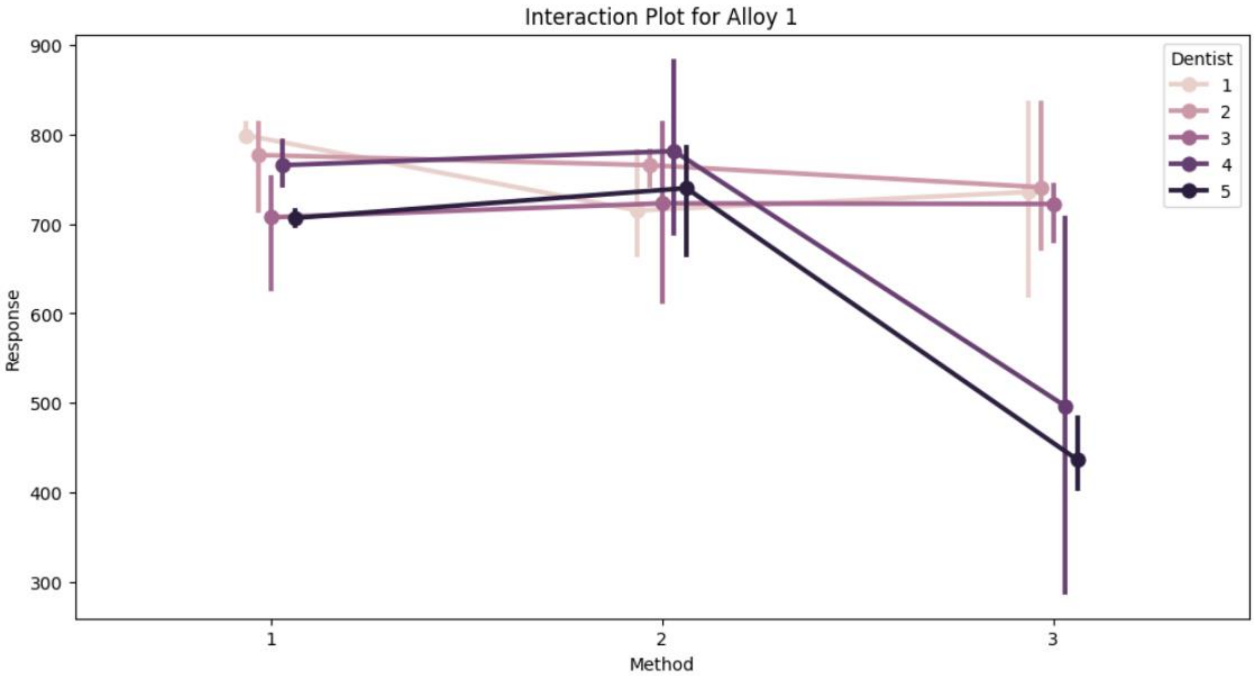
4.3 What is the interaction effect between the dentist and method on the hardness of dental implants for each type of alloy?

Ensuring the optimal hardness of dental implants is crucial for their durability and functionality. This report investigates whether the hardness of dental implants is influenced by the method used to create them and by the dentist performing the procedure. Specifically, we examine this interaction effect for two types of alloys, referred to as Alloy 1 and Alloy 2. Understanding these dynamics will help in standardizing best practices and potentially highlight any specific method-dentist combinations that yield superior implant hardness.

- objectives

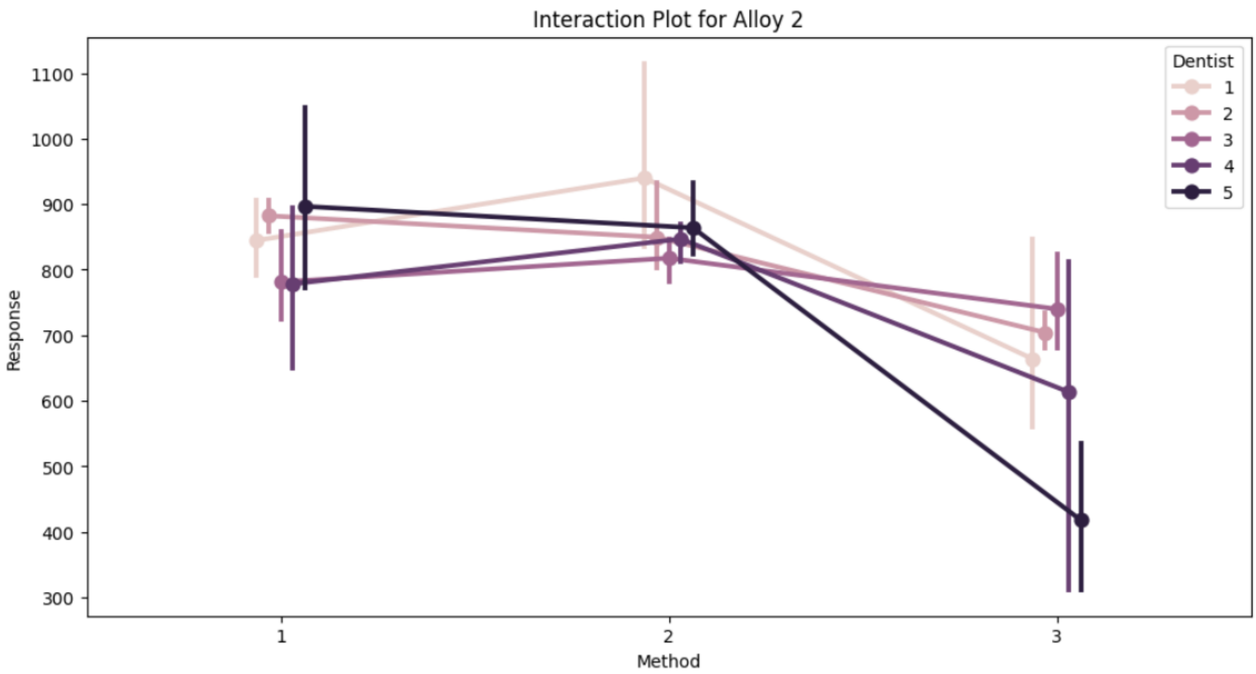
Objective 1: To determine if there is a significant interaction effect between the method and dentist on the hardness of dental implants for Alloy 1.
Objective 2: To determine if there is a significant interaction effect between the method and dentist on the hardness of dental implants for Alloy 2.

- **Hypotheses**
  Null Hypothesis (H_0): There is no interaction effect between the dentist and method on the hardness of dental implants.
  Alternative Hypothesis (H_a): There is an interaction effect between the dentist and method on the hardness of dental implants.
- **Methodology**
  An Analysis of Variance (ANOVA) was conducted to test for interaction effects between methods and dentists. Separate analyses for Alloy 1 and Alloy 2 were performed using a general linear model to assess how method and dentist interactively affect the hardness of dental implant
- Interaction Plot: for alloy1



- Stability in Methods 1 and 2: Hardness is mostly stable across different dentists for methods 1 and 2.
- Drop in Method 3: There's a noticeable drop in hardness for all dentists when using method 3, especially for dentists 4 and 5.
- Dentists 4 and 5: These dentists show a bigger decrease in hardness with method 3, suggesting they might be more affected by this method.
- Variability in Method 3: Method 3 shows more variability in hardness, making it less reliable, especially for certain dentists.
- Key Insight: The method used and the dentist performing the procedure both affect the hardness, with method 3 being less consistent across different dentists.

- Performed anova test :
  p-value: 0.006793
  Given that the p-value is less than 0.05, we reject the null hypothesis for Alloy 1. This indicates a significant interaction effect between the Method and Dentist on the hardness of dental implants. The results suggest that the impact of the method on implant hardness depends on which dentist performs the method.
- Interaction Plot: for alloy2



- **Method 3:** This method consistently shows a large decrease in hardness across all dentists, making it less reliable for producing strong dental implants with Alloy 2.
- **Method 2 with Dentist 2:** There is a significant increase in hardness for dentist 2 with method 2, suggesting that this combination may be particularly effective.
- **Overall Consistency:** The interaction between dentists and methods shows that the effectiveness of each method varies significantly depending on the dentist, especially for method 3. This highlights the importance of selecting the right method for each dentist to ensure consistent hardness in dental implants.

- Anova test result:
- F-statistic: 19.461218 p-value: 0.000004
- Since the p-value is less than 0.05, we reject the null hypothesis for the main effect of Method. This means that the method used for dental implants significantly affects the hardness of the implants.
- Interaction Effect
  Null Hypothesis : There is no interaction effect between the dentist and the method on the hardness of dental implants. Result: Reject for Alloy 1 (significant interaction effect), Fail to reject for Alloy 2 (no significant interaction effect).

- For both Alloy 1 and Alloy 2, the ANOVA tests indicate that the method used and the dentist performing the procedure interactively affect the hardness of dental implants. This underscores the importance of considering both factors to achieve consistent quality and performance in dental implants. The findings are crucial for standardizing best practices and could assist in identifying specific method-dentist combinations that yield superior implant hardness, thereby improving the overall durability and functionality of dental implants.

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

The hardness of dental implants varies depending on the combination of dentists and methods used to manufacture the implants. To achieve this, separate analyses were conducted for two types of alloys, Alloy 1 and Alloy 2. The analysis aims to test multiple hypotheses regarding the impact of methods, dentists, and their interaction on implant hardness.

- Null Hypotheses:
- (H_0M): The means of hardness for dental implants do not differ across methods.
- (H_0D): The means of hardness for dental implants do not differ across dentists.
- (H_0I): There is no interaction effect between the dentist and the method on the hardness of dental implants.
- Alternative Hypotheses:
- (H_aM): The means of hardness for dental implants differ across methods.
- (H_aD): The means of hardness for dental implants differ across dentists.
- (H_aI): There is an interaction effect between the dentist and the method on the hardness of dental implants.

Assumptions of Two-Way ANOVA

1. **Independence of Observations**: The data should be collected and grouped independently.
2. **Normality**: The residuals (errors) of the model should be approximately normally distributed.
3. **Homogeneity of Variances**: The variances among groups should be approximately equal.

Note: The analysis was conducted even if the assumptions were not fully met.

Results and Analysis

Alloy 1

1. **Shapiro-Wilk Test**:

Normality: Data from "Dentist 1, Method 1" and "Dentist 3, Method 3" groups were not normally distributed.

All other combinations: Data was normally distributed.

2. **Levene's Test**:

p-value: Greater than 0.05, indicating equal variances across groups.

3. **Two-Way ANOVA**:

Methods: Significant differences in hardness across methods.

- **F-statistic**: 10.854287, **p-value**: 0.000284

Dentists: Significant differences in hardness across dentists.

- **F-statistic**: 3.899638, **p-value**: 0.011484

Interaction (Dentist × Method): Significant interaction effect between dentists and methods.

- **F-statistic**: 3.398383, **p-value**: 0.006793

Since the p-value for the Interaction factor is less than 0.05 (0.006793), we reject the null hypothesis. This means there is a significant interaction effect between the dentist and the method on the hardness of dental implants. Thus, we accept the alternative hypothesis.

Alloy 2

1. **Shapiro-Wilk Test**:

Normality: Data was normally distributed across all combinations of dentist and method.

2. **Levene's Test**:

p-value: Significantly less than 0.05, indicating unequal variances across methods.

3. **Two-Way ANOVA**:

Methods: Significant differences in hardness across methods.

F-statistic: 19.461218, **p-value**: 0.000004

Since the p-value for the Method factor is significantly less than 0.05, we reject the null hypothesis. This means that the means of hardness for dental implants significantly differ across methods. Thus, we accept the alternative hypothesis

Dentists: No significant differences in hardness across dentists. **F-statistic**: 1.106152, **p-value**: 0.371833

Since the p-value for the Dentist factor is greater than 0.05, we fail to reject the null hypothesis . This means that there is no significant difference in the means of hardness for dental implants across dentists. Consequently, we do not have enough evidence to accept the alternative hypothesis .

Interaction (Dentist × Method): No significant interaction effect between dentists and methods.

F-statistic: 1.922787, **p-value**: 0.093234

Methods :

F-statistic: 19.461218 p-value: 0.000004 (less than 0.05)

The p-value for the interaction C(Dentist):C(Method) is slightly greater than 0.05, so we fail to reject the null hypothesis . This indicates that there is no significant interaction effect between the dentist and the method on the hardness of dental implants. Therefore, we do not have enough evidence to accept the alternative hypothesis

- Conclusion

For Alloy 1, both the method and the dentist significantly affect implant hardness, and their interaction is also significant. In contrast, for Alloy 2, only the method significantly affects implant hardness, with no significant effect from the dentist or the method-dentist interaction. This information is vital for selecting the best practices for manufacturing dental implants to ensure optimal hardness and reliability.

5.Recommendations:

- For Football Teams:
- Implement customized training and injury prevention for strikers due to their higher probability of injuries.
- Focus on injury management strategies for forwards and wingers.
- for Quality Assurance in Packaging:
- Address quality control to reduce the proportion of gunny bags with weak breaking strengths (< 3.17 kg/cm^2).
- Ensure manufacturing processes consistently produce gunny bags with adequate strength ($\geq$ 3.6 kg/cm^2).
- For Printing Services:
- Prioritize using polished stones for printing due to their higher hardness.
- Explore methods to enhance the hardness of unpolished stones if they are to be used.
- For Dental Implants:
- Review and standardize the methods used to fabricate implants, especially focusing on Method 3, which shows inconsistencies.
- Training or standardization should be considered for dentists to ensure consistency in implant hardness across different methods.
- Further research should explore methods to reduce the variability in implant hardness based on the interaction between different dentists and methods.