Project 1

- Inferential Statistics -

Inferential Statistics

1.1.Introduction

This report presents an analysis of inferential statistics, focusing on four distinct problems. Each problem addresses specific questions related to player injuries, the breaking strength of gunny bags, The hardness of polished and unpolished stones, and Response of dental implants.

Problem 1 investigates the relationship between foot injuries and player positions within a male football team. Using data on injured and non-injured players across various positions—strikers, forwards, attacking midfielders, and wingers—the report calculates probabilities related to player injuries, helping physiotherapists understand the risk factors associated with different positions.

Problem 2 examines the breaking strength of gunny bags used in cement packaging, which is normally distributed with a known mean and standard deviation. This analysis aims to determine the proportions of bags with varying breaking strengths, providing insights into product quality and potential issues within the supply chain.

Problem 3 involves Zingaro Stone Printing, a company concerned about the suitability of unpolished stones for printing based on their hardness. The report conducts hypothesis testing to evaluate whether these stones meet the necessary hardness criteria for effective printing and compares the mean hardness of polished and unpolished stones.

Problem 4 explores the Response of dental implants, analyzing how it varies based on factors such as the method of implant, temperature treatment, alloy used, and the dentist's influence. This section includes an examination of interaction effects and provides insights into how these variables collectively impact implant hardness.

By systematically addressing these four problems, this report aims to provide valuable insights and recommendations that can inform decision-making processes in sports management, manufacturing, and dental practices.

1.2.Objectives of the Analysis

The objective of this analysis is to comprehensively examine various aspects related to injuries in a male football team, the structural integrity of gunny bags used in cement packaging, the hardness of stones for printing, and the Response of dental implants. The analysis will provide insights that can inform decision-making, quality control, and operational improvements in the following areas:

1. **Injury Analysis in Football Players**:
    - To evaluate the prevalence of foot injuries among players based on their positions and determine the probability of injuries occurring in specific roles (e.g., striker, forward, etc.). This analysis aims to identify potential risk factors associated with different playing positions, which could lead to targeted injury prevention strategies.
2. **Quality Assessment of Gunny Bags**:
    - To analyze the breaking strength of gunny bags to understand their durability and reliability in cement packaging. This includes determining the proportions of bags that fall below certain strength thresholds and assessing the risk of wastage or pilferage. The findings will support quality assurance efforts and enhance the supply chain management process.
3. **Evaluation of Stone Hardness for Printing**:
    - To assess the suitability of polished versus unpolished stones for printing based on their hardness. This includes determining if unpolished stones meet the necessary hardness criteria and comparing the mean hardness levels of both stone types. The results will guide material selection and production processes at Zingaro.
4. **Analysis of Dental Implant Hardness**:
    - To investigate how the Response of dental implants varies based on different factors, including dentists, treatment methods, and their interactions. This will help identify any significant differences in Response due to specific methods or practitioner preferences, providing insights for improving implant quality and performance.

2.Key Answers for the key questions

2.1.Problem - 1:

This report analyzes foot injuries among players in a male football team. By calculating injury-related probabilities across positions—Striker, Forward, Attacking Midfielder, and Winger—we aim to provide insights for injury prevention.

-1.1 Probability of Injury Among Players:

The probability that a randomly chosen player suffers a foot injury is calculated as follows:

Formula:

P(Injury) = Total Injured Players / Total Players

Data Used:

- Total Injured Players = 145
- Total Players = 235

Calculation:

= 145/235

≈ 0.617

This indicates that there is a **61.7%** chance that a randomly selected player has sustained an injury.

-1.2 Probability of Being a Forward or Winger :

To determine the probability that a player is either a forward or a winger,

Formula:

P(Forward or Winger) = P(Forward) + P(Winger) / Total Players

Data Used:

- Total Forwards = 94
- Total Wingers = 29

Calculations:

= 94 + 29 / 235

≈ 0.523

This results in a probability of approximately **52.3%** that a randomly chosen player plays in either the forward or winger position.

-1.3 Probability of Being an Injured Striker :

The probability that a randomly chosen player is a striker who has sustained an injury is given by:

Formula:

P(Striker and Injury) = Injured Strikers / Total Players

Data Used:

- Injured Strikers = 45

Calculation:

P(Striker and Injury) = 45 / 235

= 0.191

Thus, there is about a **19.1%** chance that a randomly selected player is both a striker and injured.

-1.4 Probability of an Injured Player Being a Striker

Finally, the probability that a randomly chosen injured player is a striker is calculated as follows:

Formula:

P(Striker | Injury) = Injured Strikers / Total Injured Players

Data Used:

- Injured Strikers = 45
- Total Injured Players = 145

Calculation:

P(Striker | Injury) = 45 / 145

≈ 0.310

This indicates that approximately **31.0%** of injured players are strikers.

Conclusion: The analysis of foot injuries among the football team reveals significant insights into the prevalence of injuries across different player positions.

1. **Injury Rate**: With a probability of **61.7%** for players to suffer a foot injury, it is evident that injuries are a common occurrence within the team. This high rate underscores the need for effective injury prevention strategies and rehabilitation programs to safeguard player health.
2. **Position-Specific Risk**: The probability of being either a forward or a winger is approximately **52.3%**, indicating that over half of the players occupy these positions. This suggests that these roles may be particularly vulnerable to injuries, necessitating targeted training and conditioning programs that address the specific demands of these positions.
3. **Injured Strikers**: The analysis indicates that there is a **19.1%** probability that a randomly selected player is both a striker and injured. This highlights the potential risk associated with the striker position, which may involve more intense physical demands and greater exposure to injury.
4. **Injured Player Profile**: Finally, with approximately **31.0%** of injured players being strikers, this data suggests that strikers are disproportionately affected by injuries compared to other positions. This insight may warrant a closer examination of their training routines, playing styles, and injury prevention measures.

In conclusion, the findings suggest a pressing need for the team to implement comprehensive injury prevention protocols, particularly focused on strikers and players in high-risk positions. By addressing these concerns, the team can improve player safety and performance, ultimately enhancing overall team success.

2.2.Problem - 2:

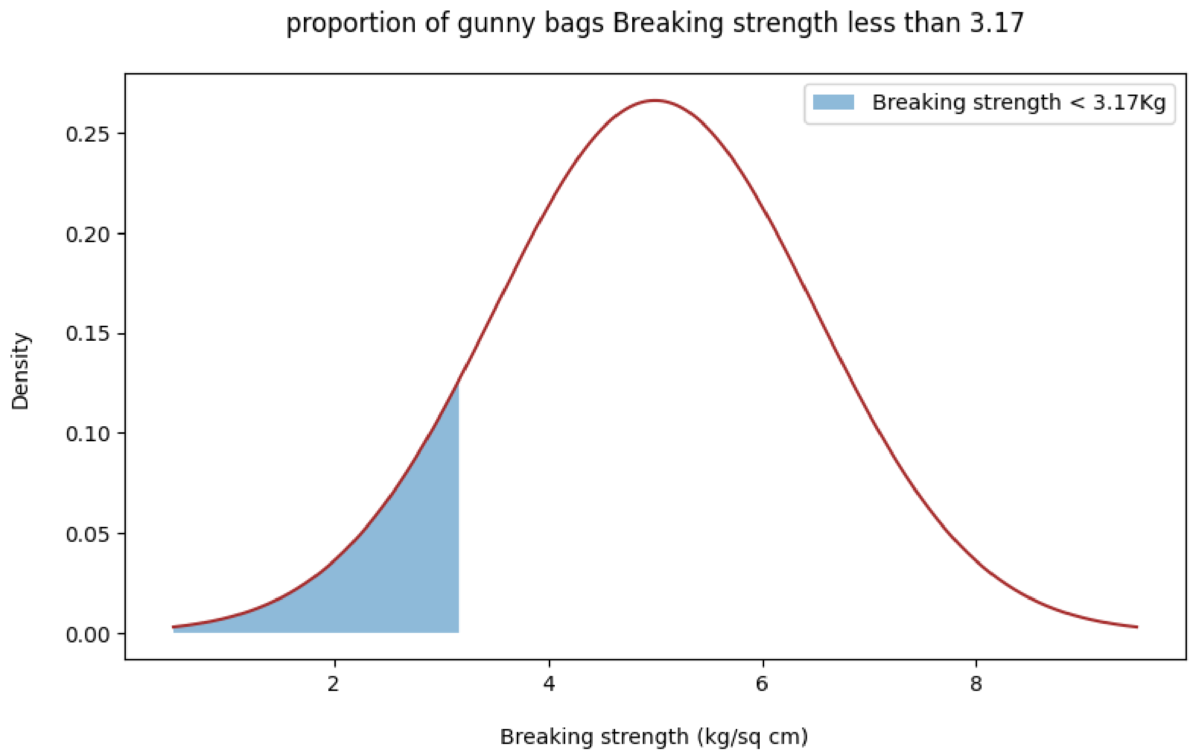
This Problem analyzes the breaking strength of gunny bags used for cement packaging. By assessing the strength distribution, we aim to identify quality issues that may contribute to wastage or pilferage in the supply chain, providing insights for the quality team to improve packaging operations.

-2.1 Proportion of Bags with Strength < 3.17 kg/cm² :

The Calculated Z-score ≈ - 1.22

Cumulative Probability ≈ 0.111

Figure 1. proportion of gunny bags Breaking strength less than 3.17



Interpretation:

The graph illustrates the distribution of the breaking strength of gunny bags used for packaging cement, which follows a normal distribution with a mean of 5 kg/sq cm and a standard deviation of 1.5 kg/sq cm. The x-axis represents the breaking strength in kg/sq cm, while the y-axis displays the probability density.

The brown curve depicts the probability density function (PDF) of the breaking strength, indicating the likelihood of various breaking strengths occurring. The shaded area under the curve, extending from the left up to 3.17 kg/sq cm, represents the proportion of gunny bags with a breaking strength less than 3.17 kg/sq cm.

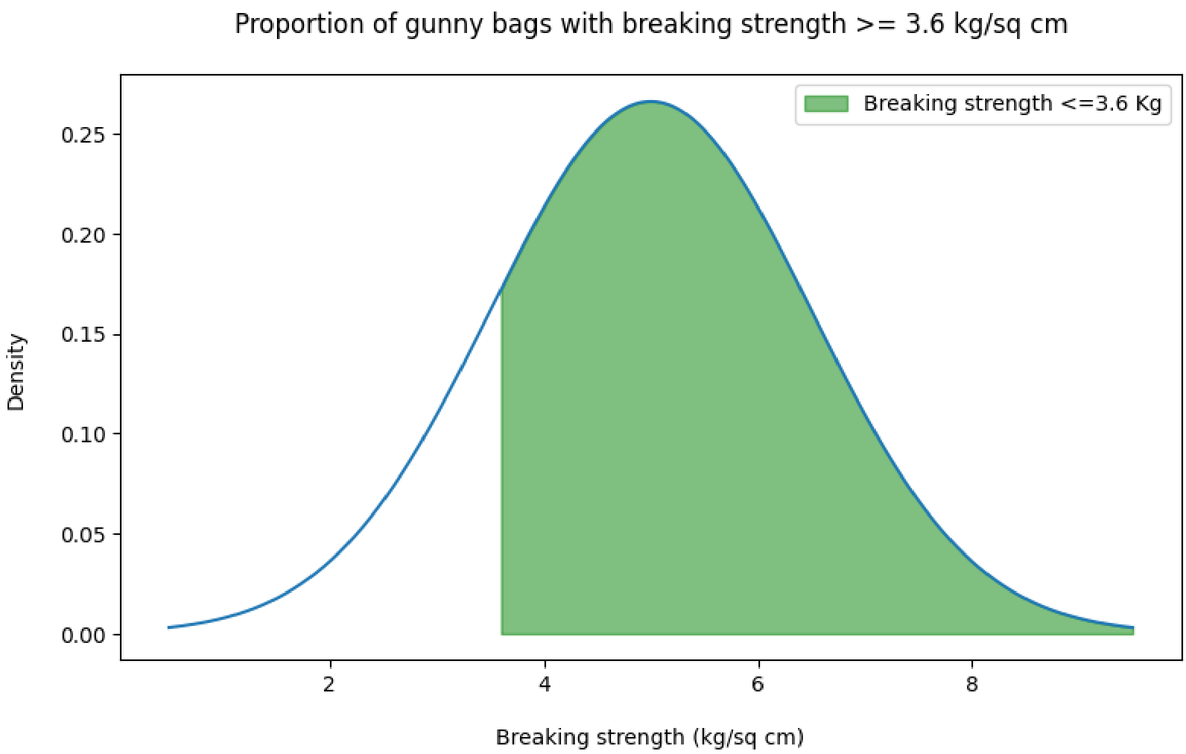
Conclusion: Approximately **11.1%** of gunny bags exhibit a breaking strength below 3.17 kg/sq cm. This suggests a significant portion of bags may not meet minimum quality standards, raising concerns about potential wastage and pilferage.

-2.2 Proportion of Bags with Strength ≥ 3.6 kg/cm² :

The Calculated Z-score ≈ - 0.93

Cumulative Probability ≈ 0.175

Figure 2. Proportion of gunny bags with breaking strength 3.6 kg/sq cm



Interpretation:

The graph illustrates the distribution of the breaking strength of gunny bags used for packaging cement, following a normal distribution with a mean of 5 kg/sq cm and a standard deviation of 1.5 kg/sq cm. The x-axis represents the breaking strength in kg/sq cm, while the y-axis displays the probability density.

The curve depicts the probability density function (PDF) of the breaking strength, indicating the likelihood of different breaking strengths occurring. The shaded area, filled in green, represents the proportion of gunny bags with a breaking strength less than or equal to 3.6 kg/sq cm.

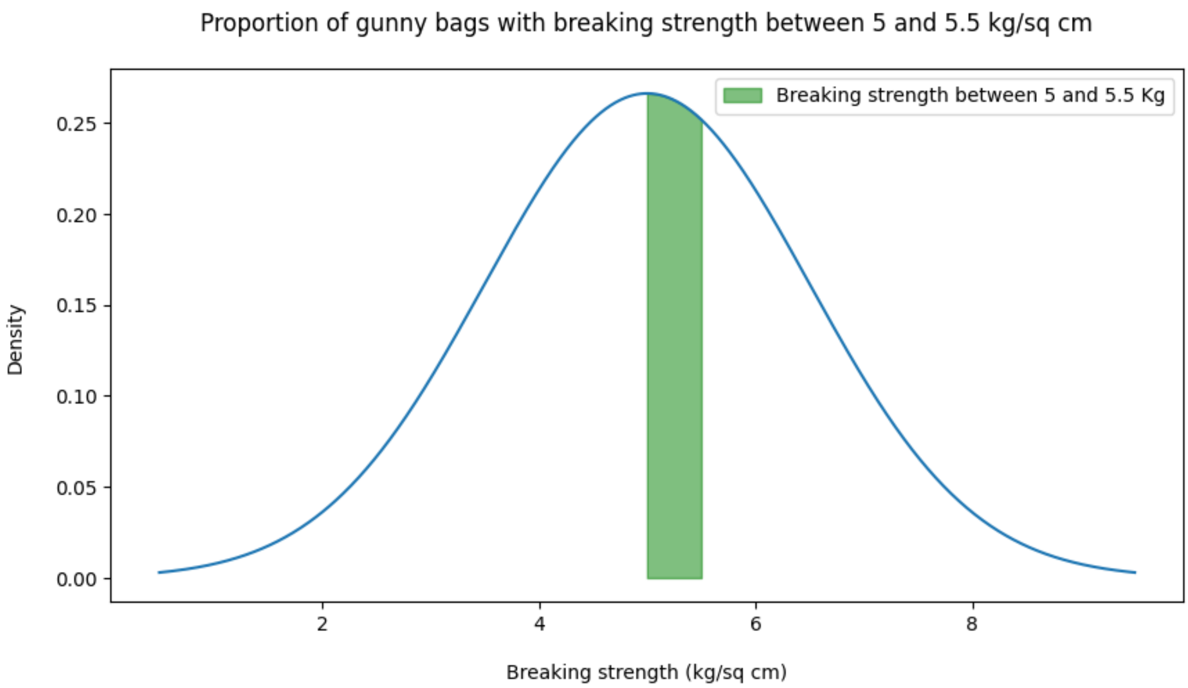
Conclusion: About **82.5% (100 - 17.5%)** of gunny bags have a breaking strength of at least 3.6 kg/cm². This indicates that the vast majority of bags meet or exceed the minimum strength requirement, suggesting good quality in the packaging material. However, there is still a significant proportion of bags that may be close to the lower threshold, warranting monitoring for potential quality issues.

-2.3 Proportion of Bags with Strength Between 5 and 5.5 kg/cm² :

The calculated z-score for the breaking strength of **5 kg/cm²** ≈ 0.0

The calculated z-score for the breaking strength of **5.5 kg/cm²** ≈ 0.33

Figure 3. Proportion of gunny bags with breaking strength between 5 and 5.5 kg/sq cm



Interpretation:

The graph illustrates the distribution of the breaking strength of gunny bags used for packaging cement, following a normal distribution with a mean of 5 kg/sq cm and a standard deviation of 1.5 kg/sq cm. The x-axis represents breaking strength in kg/sq cm, while the y-axis displays probability density.

The curve depicts the probability density function (PDF) of the breaking strength, indicating the likelihood of different strengths. The shaded area, filled in green, represents the proportion of gunny bags with a breaking strength between 5 kg/sq cm and 5.5 kg/sq cm, highlighting the subset of bags that meet the desired strength criteria. This information is crucial for assessing packaging quality and reliability.

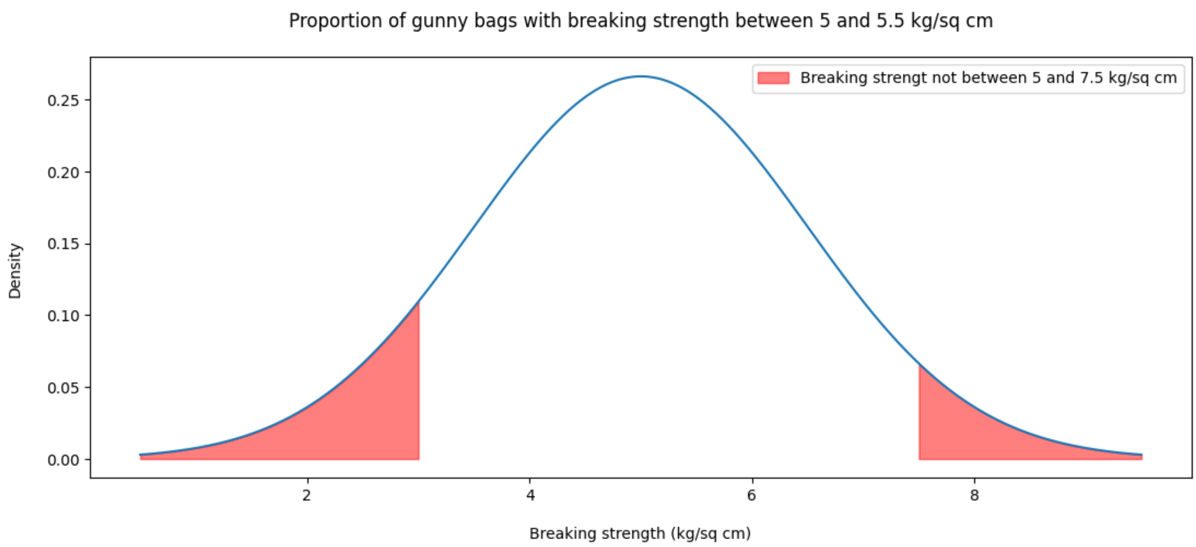
Conclusion: The analysis shows that **12.9%** of gunny bags fall within the optimal strength range of 5 to 5.5 kg/sq cm. This range is ideal for ensuring the integrity of the bags during handling and transport.

-2.4 Proportion of Bags NOT Between 3 and 7.5 kg/cm² :

The calculated z-score for the breaking strength of **3 kg/cm²** ≈ 1.33

The calculated z-score for the breaking strength of **7.5 kg/cm²** ≈ 1.67

Figure 4. Proportion of gunny bags with breaking strength between 5 and 5.5 cm



Interpretation:

The graph illustrates the distribution of the breaking strength of gunny bags used for packaging cement, following a normal distribution with a mean of 5 kg/sq cm and a standard deviation of 1.5 kg/sq cm. The x-axis represents breaking strength in kg/sq cm, while the y-axis shows probability density.

The shaded areas in red indicate the proportion of gunny bags that do not fall within the strength range of 5 kg/sq cm to 7.5 kg/sq cm, encompassing both lower and upper tails.

Conclusion: Approximately **13.9%** of gunny bags have a breaking strength that falls outside the range of 3 to 7.5 kg/cm². This suggests that a small but notable fraction of bags either do not meet the minimum strength requirement or exceed the maximum threshold. Such outliers may indicate potential quality control issues or variability in the material, highlighting the need for further investigation to ensure consistent packaging strength.

2.3.Problem - 3:

Zingaro has expressed concerns about the quality of unpolished stones, questioning their suitability for printing applications. Additionally, a comparative analysis of the hardness of polished and unpolished stones has been conducted to determine if there are significant differences.

-3.1 Testing the Suitability of Unpolished Stones:

-Hypothesis Testing for Suitability of Unpolished Stones:

Null Hypothesis (H0): Unpolished stones are suitable for printing.

Alternative Hypothesis (H1): Unpolished stones are not suitable for printing.

Hypothesis Test:

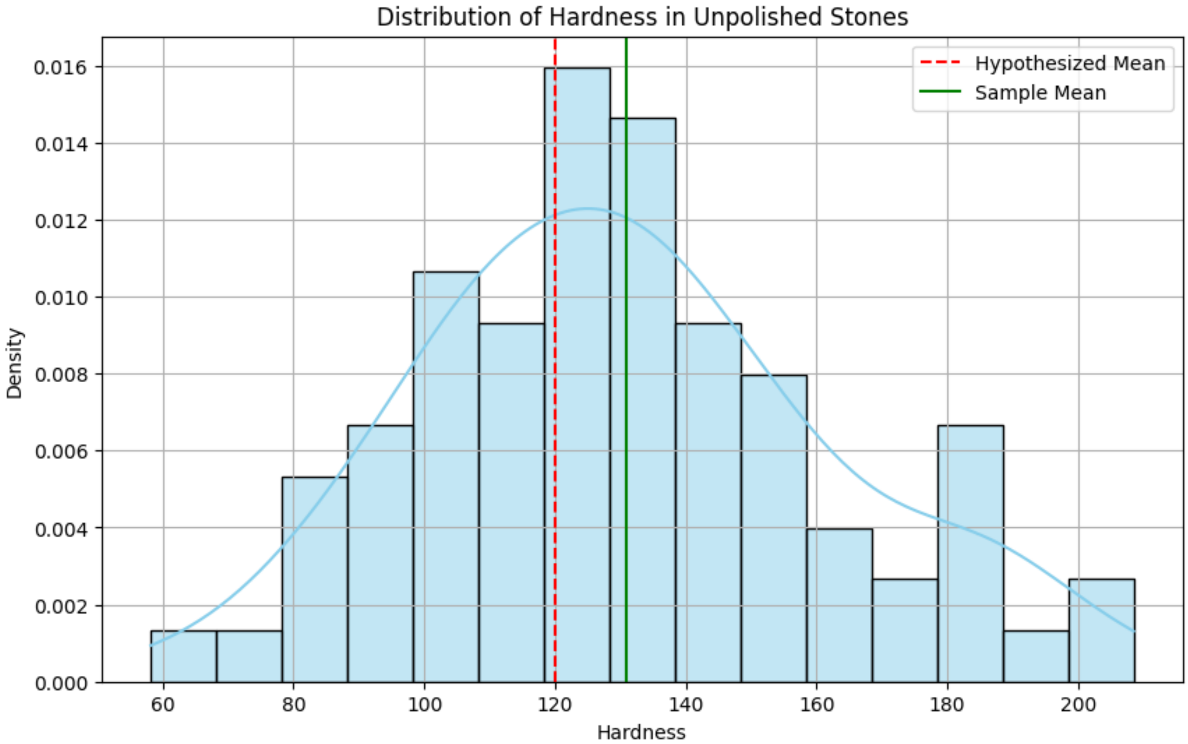
- **Significance Level (α)**: 0.05

Test: One-Sample t-Test

Assumptions:

1. **Normality**:
   - The sample data (hardness of unpolished stones) should be approximately normally distributed. Although the sample size is large (typically n > 30), the t-test is robust to violations of normality due to the Central Limit Theorem.
2. **Independence**
   - The observations in the sample must be independent. The hardness of one stone should not influence or be related to the hardness of another stone. Independence can be ensured through proper sampling methods.
3. **Random Sampling**
   - The data should be collected through a random sampling process, ensuring that the sample is representative of the broader population of unpolished stones. This approach helps in generalizing the findings to the entire population.

Figure 5. Distribution of Hardness in Unpolished Stones



Interpretation of the Plot: Distribution of Hardness in Unpolished Stones :

The distribution plot visually represents the hardness of unpolished stones, showing that the hardness values are normally distributed. The histogram and kernel density estimate indicate a concentration of values around the sample mean of 134.11 kg/sq cm. The dashed red line represents the hypothesized mean of 120 kg/sq cm, which the sample mean exceeds. This suggests that, on average, the hardness of unpolished stones is above the hypothesized threshold, potentially indicating suitability for printing applications. Further statistical analysis, such as hypothesis testing, will confirm these findings.

Test Statistic Calculation:

- The t-statistic is calculated using the formula:
- t = (mean_unpolished − mean0) / (std_dev / Total number of unpolished ** 0.5)
- t-statistic that we derived = - 4.164480854891034

P-Value Calculation:

- The p-value is calculated using the cumulative distribution function (CDF):
- p-value = $P(T \leq t)$ = stats.t.cdf(tstat,df=nunp−1)
- P- Value that we derived = 4.1734882193357195e-05
- p_value < α, Reject null hypothesis: Unpolished stones may not be suitable for printing

Summary:

1. **Testing the Suitability of Unpolished Stones** :
   - A one-sample t-test was conducted to assess whether unpolished stones are suitable for printing. The null hypothesis stated that they are suitable, while the alternative suggested they are not.
   - With a significance level of 0.05, the calculated t-statistic was -4.16 and the p-value was approximately 4.17e-05, indicating that the p-value is less than α. Therefore, we reject the null hypothesis, concluding that unpolished stones may not be suitable for printing applications.

-3.2 Testing the Mean Hardness of Polished vs. Unpolished Stones:

- Hypothesis Testing for Hardness Comparison:

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

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

Hypothesis Test:

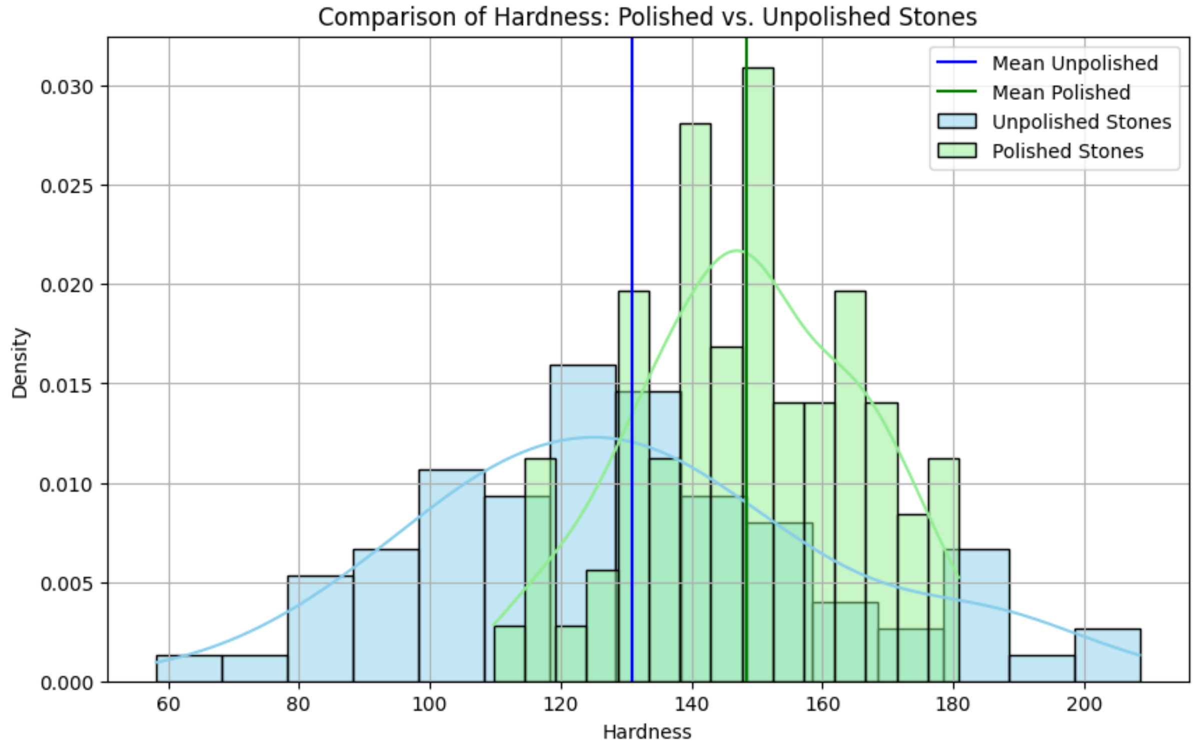
- **Significance Level (α)**: 0.05

Test: Independent Samples t-Test

Assumptions:

1. Normality
   - The hardness values in both groups (polished and unpolished stones) should be approximately normally distributed. If both groups have large sample sizes (n>30), the Independent Samples t-Test remains valid even if normality is slightly violated.
2. Independence
   - The observations within each group and between the two groups must be independent. For example, the hardness of polished stones should not affect the hardness of unpolished stones. Random sampling typically ensures this independence.
3. Equal Variances (Homogeneity of Variance)
   - The variances of the two groups should be similar. This can be tested using Levene’s test or an F-test. If the variances are significantly different, a modified version of the Independent Samples t-Test (Welch's t-test) can be employed, which does not assume equal variances.
4. Random Sampling
   - Both groups should be sampled randomly to ensure that the results are representative of the overall population. This approach aids in making valid inferences about the mean hardness of both polished and unpolished stones.

Figure 6. Comparison of Hardness: Polished vs. Unpolished Stones



Interpretation of the Plot: Comparison of Hardness in Polished vs. Unpolished Stones

The distribution plot compares the hardness of polished and unpolished stones, showing both datasets are normally distributed. The histogram and kernel density estimates reveal that the polished stones (mean of 147.79 kg/sq cm) have higher hardness values than unpolished stones (mean of 134.11 kg/sq cm). This suggests a significant difference in hardness, indicating that polished stones may be more suitable for printing applications. Further statistical analysis will confirm these findings.

Test Statistic Calculation and **P-Value Calculation**:

- The t-statistic and p-value is calculated using the formula:
- t,p=stats.ttest_ind_from_stats(mean1=meanunp,std1=std_dev,nobs1=nunp ,mean2=meanpo,std2=std_po,nobs2=npo)
- t-statistic that we derived = -3.242089792424464
- P- Value that we derived = 0.0014661977202026972
- p_value < α, Reject null hypothesis : There is a significant difference between polished and unpolished stones.

Summary:

Comparative Analysis of Hardness:

- An independent samples t-test compared the mean hardness of polished and unpolished stones. The null hypothesis posited that the mean hardness of both groups is equal, while the alternative suggested a difference.
- The t-statistic calculated was -3.24, with a p-value of approximately 0.0015. As this p-value is less than α (0.05), we reject the null hypothesis, concluding that there is a significant difference in hardness between polished and unpolished stones, with polished stones demonstrating greater hardness.

Recommendations:

1. **Quality Control**: Given that unpolished stones may not meet the necessary hardness standards for printing, Zingaro should consider implementing stricter quality control measures to ensure that only suitable materials are used.
2. **Further Research**: It may be beneficial to conduct additional studies focusing on different batches of unpolished stones to confirm these findings and explore any potential improvements in their hardness through treatment or polishing.
3. **Investment in Polishing**: Since polished stones have been shown to have significantly higher hardness, Zingaro should evaluate the cost-effectiveness of investing in polishing processes to enhance the quality and suitability of their stones for printing applications.
4. **Market Communication**: The results of this analysis can be used to communicate with clients about the quality of Zingaro's products, reinforcing confidence in the suitability of polished stones for their applications.

By addressing these areas, Zingaro can improve product quality and customer satisfaction while reducing potential wastage and dissatisfaction in the supply chain.

2.4.Problem - 4:

Understanding the Response of dental implants is crucial for ensuring quality and performance. This report addresses the variations in Response based on different dentists, methods, and their interaction effects for two types of alloys.

-4.1 Response Variation Based on Dentists:

Null Hypothesis (H0): There is no significant difference in implant response across different dentists.
Alternative Hypothesis (H1): There is a significant difference in implant response across different dentists.

Significance Level (α): 0.05

Test: One – Way ANOVA

Objective: To compare the means of the response variable (Response) across different levels of a single categorical factor (e.g., Dentists or Methods).

Assumptions:

1. **Normality**:
   - The sample data for dentists and their responses consists of a large sample size, typically greater than 30 ($n > 30$). According to the Central Limit Theorem, when the sample size is sufficiently large, the distribution of the sample means will approximate a normal distribution, regardless of the original distribution of the population. Therefore, we can reasonably assume that the data is normally distributed.

2. **Homogeneity of Variances**:

   Null hypothesis (H_0): The variances are equal (homogeneity of variances).

   Alternate hypothesis (H_1): The variances are not equal (heterogeneity of variances).

   The Based on the results of **Welch's ANOVA** for the "Dentist" variable:

   - **F-value = 1.745**
   - **p-value = 0.159**

     Since the p-value (0.159) is greater than 0.05, we fail to reject the null hypothesis. This means there is no significant difference in the Response of implants depending on the dentist when the assumption of unequal variances is considered.

3. **Independence**:
   - Observations are independent of each other. Since each measurement is taken independently, this assumption is satisfied.

Table 1. Hypothesis Testing for the Response of implants vary depending on dentists:

Source	Sum of Squares (SS)	Mean Square (MS)	F-Statistic	p-value
Dentist	157,794.56	39,448.64	1.935	0.112
Residual	1,733,301.00	20,391.78	-	-

Interpretation:

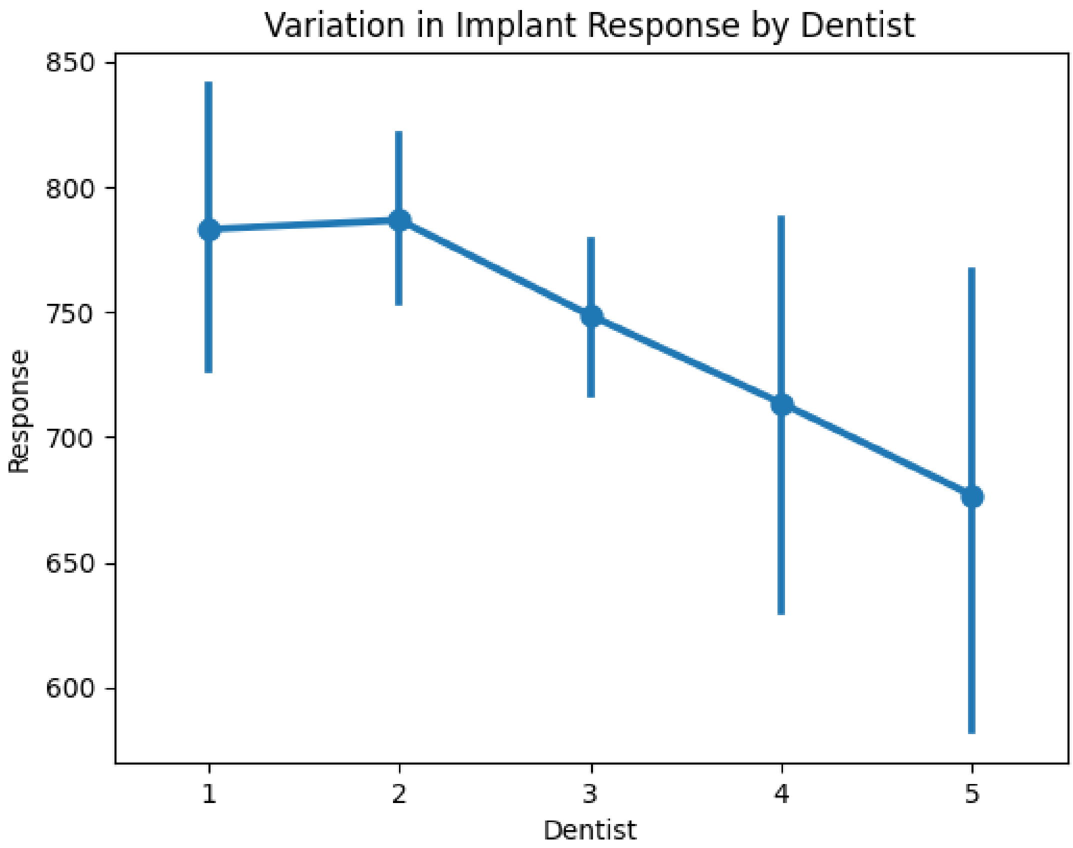
- **Sum of Squares (SS)**: This represents the total variability in the Response response attributed to the differences between the dentists (157,794.56) and the remaining unexplained variability (1,733,301.00).
- **Mean Square (MS)**: This is calculated by dividing the sum of squares by the respective degrees of freedom (df). For the dentist variable, the mean square is 39,448.64, while the residual (error) mean square is 20,391.78.

- **F-Statistic**: The F-value of 1.935 measures the ratio of the variance explained by the dentists to the unexplained variance (error). An F-statistic close to 1 suggests that the variance between dentists is not substantially greater than the variance within groups.
- **p-value**: The p-value of 0.112 indicates the probability that the differences observed between the dentists occurred by chance. Since this value is greater than the commonly used significance threshold of 0.05, we fail to reject the null hypothesis. This means that, statistically, there is no significant difference in the Response across dentists.

Calculation Breakdown:

1. **Sum of Squares (SS)**: The Dentist SS is calculated as the variance attributable to differences between the group means (i.e., different dentists), and the Residual SS is the variance unexplained by the model.
2. **Mean Square (MS)**: The Mean Square for Dentist is the Sum of Squares divided by the degrees of freedom (df = 4 for Dentist). Similarly, the Residual Mean Square is the Residual SS divided by its degrees of freedom (df = 85).
3. **F-Statistic**: The F-statistic is computed as the ratio of the Dentist MS to the Residual MS. A higher F-value indicates greater variance between groups compared to within-group variance, but in this case, the F-value is relatively low (1.935), suggesting limited differences between dentists.
4. **p-value**: The p-value is used to determine statistical significance. Here, the p-value of 0.112 is above 0.05, indicating that any differences observed between dentists could be due to random variation rather than a systematic effect.

Figure 7. Variation in Implant Response by Dentist



Interpretation:

The plot shows the relationship between different dentists (x-axis) and the response (implant Response, y-axis) across five dentists. Here's a breakdown of the key insights:

1. **Dentist 1 and 2**:
    - Both have similar average Response values (around 800).
    - However, Dentist 1 has a much larger variability (wider error bars), suggesting more inconsistency in implant Response.
2. **Dentist 3**:
    - The average Response declines compared to Dentists 1 and 2 (around 750).
    - Variability is moderate but less than Dentist 1.

3. **Dentist 4 and 5**:
   - There's a further drop in average Response, with Dentist 5 having the lowest average response (around 700).
   - Dentist 5 also shows large variability (wide error bars), indicating less precision.

Conclusion:

- There is a general downward trend in implant Response from Dentists 1 to 5.
- Dentist 1 and 2 produce harder implants on average, but Dentist 1 has high variability, indicating inconsistent results.
- Dentists 4 and 5 yield lower implant Response, with Dentist 5 showing significant variation in outcomes.

This aligns with the statistical analysis suggesting that both the dentist and their methods significantly affect implant Response.

-4.2 Response Variation by Methods:

Objective: To determine whether the method used affects the Response of dental implants.

1. Hypotheses

- **Null Hypothesis (H_0)**: There is no significant difference in the Response of dental implants across the different methods.

  $H0: \mu1=\mu2=\mu3$

  Where $\mu1, \mu2, \mu3$ are the mean Response values for each method.

- **Alternative Hypothesis (H_1)**: At least one method leads to a significantly different Response of dental implants.

  $H1: \mu1 \neq \mu2 \neq \mu3$.

Test Used: One-way ANOVA

Assumptions:

1.Normality:

- The sample data for Methods and their responses consists of a large sample size, typically greater than 30 ($n > 30$). According to the Central Limit Theorem, when the sample size is sufficiently large, the distribution of the sample means will approximate a normal distribution, regardless of the original distribution of the population. Therefore, we can reasonably assume that the data is normally distributed.

2.Homogeneity of Variances:

Null hypothesis (H_0): The variances are equal (homogeneity of variances).

Alternate hypothesis (H_1): The variances are not equal (heterogeneity of variances).

Proceeding with the Assumption of no significant difference, we fail to reject the null hypothesis.

3.Independence:

- Observations are independent of each other. Since each measurement is taken independently, this assumption is satisfied.

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Table 2. ANOVA Results for Response Variation by Methods:

Source	df	Sum of Squares (SS)	Mean Square (MS)	F-statistic	p-value
Method	2	5,93,427.49	2,96,713.74	19.893	0
Residual	87	12,97,668.07	14,915.73	-	-

- **F-statistic**: The F-value is 19.893, indicating that the variance between methods is much larger than the variance within methods.
- **p-value**: The p-value is **0.000**, which is less than the significance level of 0.05, allowing us to reject the null hypothesis.

Conclusion: Since the p-value is significantly less than 0.05, we reject the null hypothesis. The method used for dental implants significantly affects the Response.

Tukey's HSD Post-Hoc Test Results:

After finding that Method has a significant effect on implant Response, the Tukey HSD test helps identify which specific methods differ in their effect.

Table 3. Tukey HSD Results for Response Variation by Methods:

Group 1	Group 2	Mean Difference	p-value	95% CI Lower	95% CI Upper	Significantly Different?
Method 1	Method 2	10.43	0.9415	-64.76	85.63	No
Method 1	Method 3	-166.8	0	-241.99	-91.61	Yes
Method 2	Method 3	-177.23	0	-252.43	-102.04	Yes

Interpretation:

- Method 1 vs Method 2: The mean difference is 10.43, and the p-value is 0.9415, meaning there is no significant difference in the implant Response between these two methods.

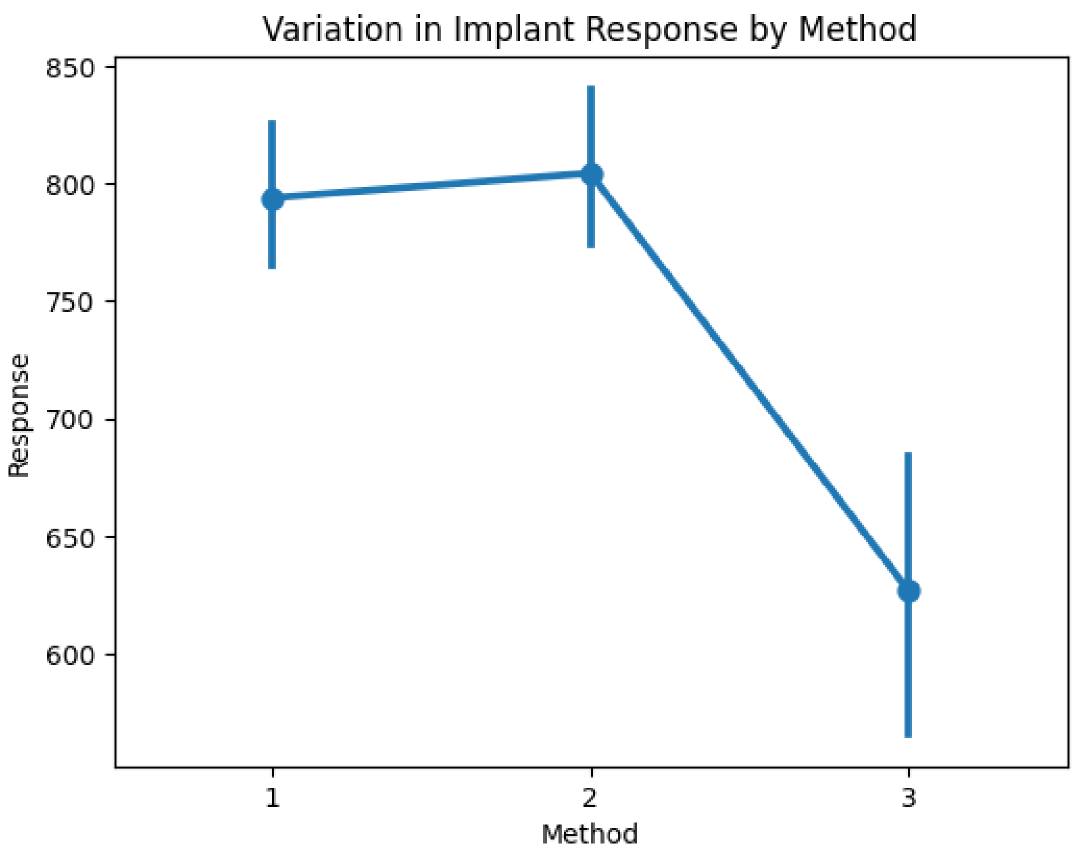
- Method 1 vs Method 3: The mean difference is -166.80, and the p-value is 0.0000. This indicates that Method 3 results in a significantly lower Response than Method 1
- Method 2 vs Method 3: The mean difference is -177.23, and the p-value is 0.0000. Similarly, Method 3 leads to significantly lower Response compared to Method 2**.**

Conclusion: ANOVA results show that the method of implantation has a statistically significant effect on implant Response ($p = 0.000$).

- **Tukey's HSD post-hoc test** reveals that:
  - Method 3 produces significantly lower Response than both Method 1 and Method 2.
  - There is no significant difference between the Response achieved by Method 1 and Method 2.

These results suggest that if implant Response is a priority, Method 1 or Method 2 would be preferable over Method 3, as the latter leads to significantly lower Response levels.

Figure 8. Variation in Implant Response by Method



Interpretation:

The plot displays the relationship between the different methods (x-axis) used and the implant Response (response) on the y-axis. Here’s a concise analysis:

1. **Method 1 and 2**:
    - Both methods result in similar average Response values (around 800).
    - Method 2 shows slightly higher variability (wider error bars), but the difference is not substantial.
2. **Method 3**:
    - There is a significant drop in the average implant Response (around 650).
    - Method 3 also has the largest variability, indicating a wide range of responses and lower consistency in outcomes.

Conclusion:

- Method 3 produces significantly lower implant Response compared to Methods 1 and 2, which yield similar results.
- Method 3's large variability suggests it may be less reliable or consistent.
- This visual evidence supports the idea that the method significantly influences the implant Response, as identified in the statistical analysis.

-4.3 Interaction Effect of Dentist and Method:

1. Objective

The goal is to determine whether there is a significant interaction effect between Dentist and Method on the Response of dental implants, analyzed separately for each type of Alloy.

Alloy 1:

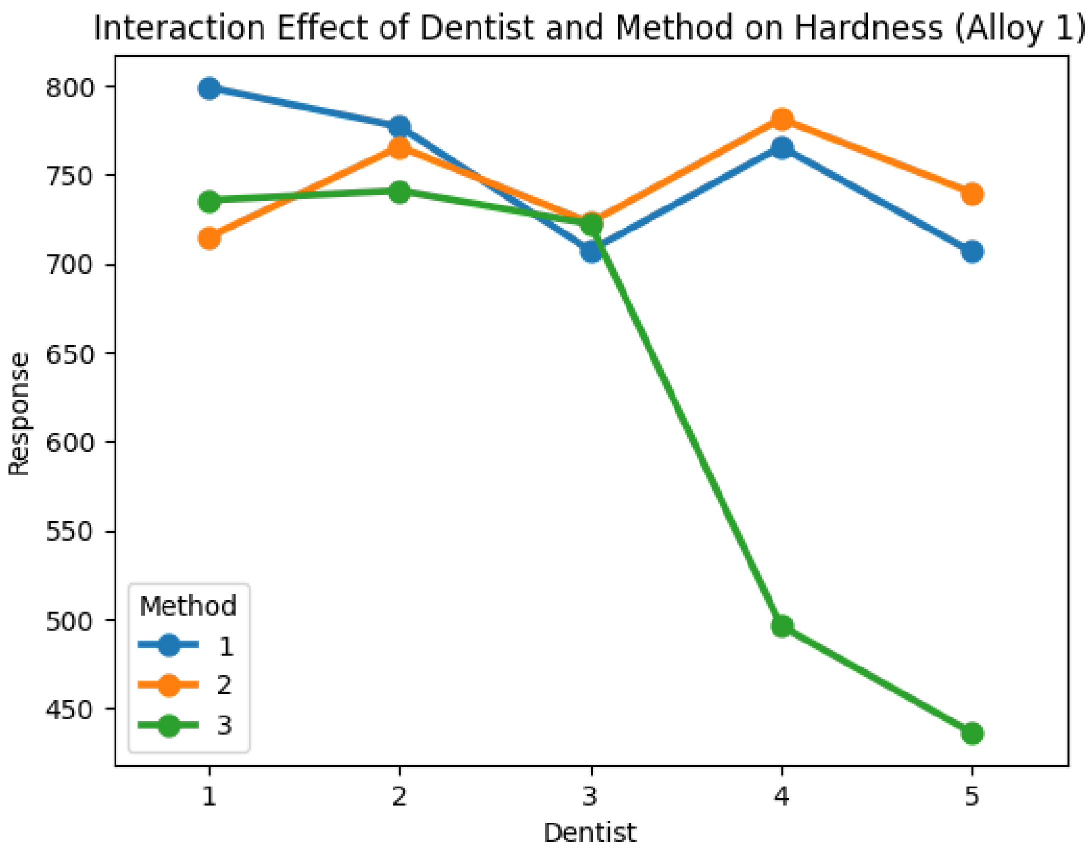
Table 4. ANOVA Results for Alloy 1

Source	**df**	**Sum of Squares (SS)**	**Mean Square (MS)**	**F-statistic**	**p-value**
Dentist	4	1,06,683.69	26,670.92	3.9	0.011
Method	2	1,48,472.18	74,236.09	10.854	0
Alloy	1	4,178.98	4,178.98	0.611	0.441
Dentist:Method	8	2,00,881.35	25,110.17	3.671	0.004
Dentist:Alloy	4	15,943.98	3,985.99	0.583	0.677
Method:Alloy	2	16,215.74	8,107.87	1.185	0.32
Dentist:Method:Alloy	8	12,954.58	1,619.32	0.237	0.981
Residual	30	2,05,180.00	6,839.33	-	-

Interaction Plot

To visualize the interaction between Dentist and Method on the Response of implants for Alloy 1,

Figure 9. Interaction Effect of Dentist and Method on Hardness (Alloy 1)



Interpretation:

This plot visualizes the interaction effect of different dentists (x-axis) and methods (color-coded lines) on the response variable (implant hardness) for Alloy 1.

Key observations:

1. **Method 1 (Blue)**:
   - The hardness remains relatively consistent across dentists, fluctuating around the 750–800 range, showing minor variation between dentists.

2. **Method 2 (Orange)**:
    - o Similarly stable, with values generally higher than Method 1 for most dentists. The hardness peaks for Dentist 3, slightly declining afterwards.
3. **Method 3 (Green)**:
    - o Exhibits a significant drop in hardness after Dentist 3. While it starts around 700 (Dentist 1), it dramatically decreases to below 500 for Dentists 4 and 5, signaling inconsistency and possibly poor performance with these dentists.

Conclusion:

- Method 3 shows a steep decline in hardness for certain dentists, especially after Dentist 3, indicating a strong interaction between the dentist and method.
- Methods 1 and 2 are more consistent across dentists with relatively minor variations in implant hardness.
- This interaction suggests that the dentist and method used together significantly influence the outcome, particularly for Method 3, where hardness varies drastically.

Alloy 2:

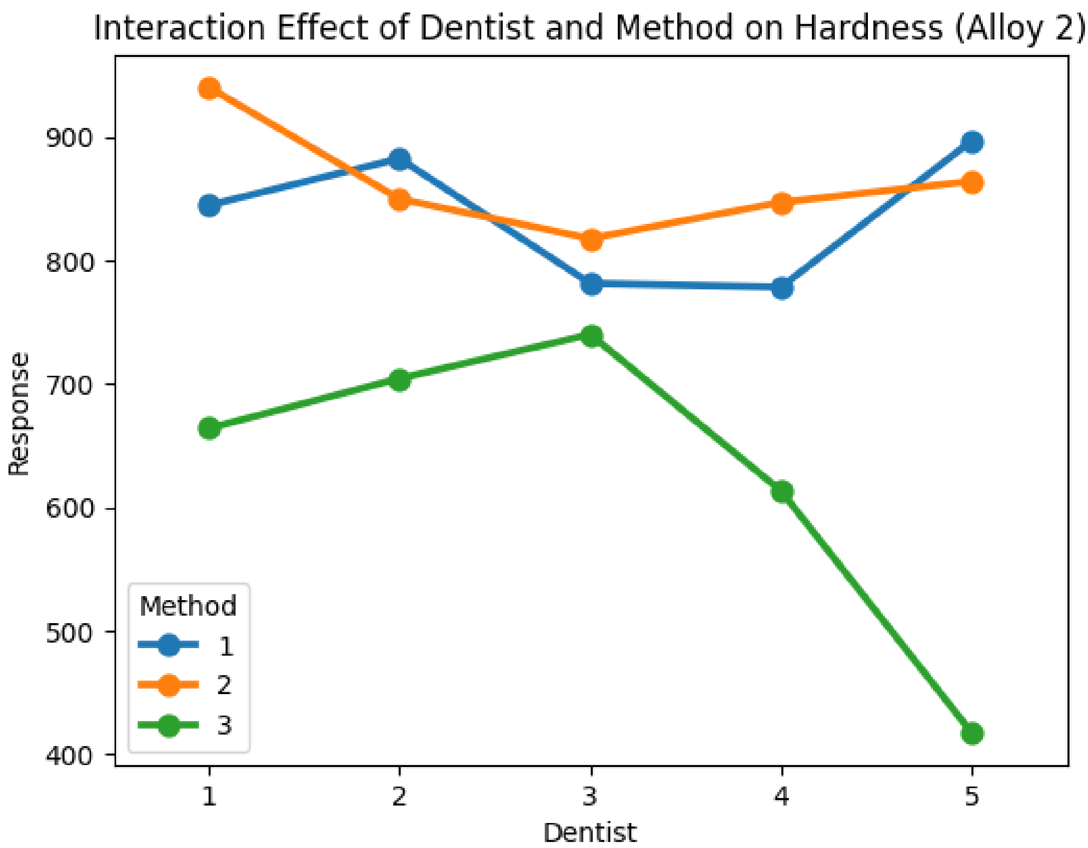
Table 5. ANOVA result for Alloy 2:

Source	**df**	**Sum of Squares (SS)**	**Mean Square (MS)**	**F-statistic**	**p-value**
Dentist	4	56797.911	14199.478	1.106	0.372
Method	2	499640.400	249820.200	19.461	0
Alloy	1	1191.271	1191.271	0.093	0.763
Dentist:Method	8	202141.630	25267.704	1.968	0.086
Dentist:Alloy	4	51183.981	12795.995	0.997	0.425
Method:Alloy	2	138209.370	69104.685	5.383	0.010
Dentist:Method:Alloy	8	30419.535	3802.442	0.296	0.962
Residual	30	385104.667	12836.822	-	-

Interaction Plot

To visualize the interaction between Dentist and Method on the Response of implants for Alloy 2,

Figure 10. Interaction Effect of Dentist and Method on Hardness (Alloy 2)



Interpretation

This plot illustrates the interaction effect between different dentists and methods on the response variable (hardness) for Alloy 2.

Key observations:

1. **Method 1 (Blue)**:
   - The response (hardness) remains relatively stable across dentists, with some variation. The lowest hardness is observed for Dentist 2, but the pattern remains consistent and higher than Method 3 overall, ranging around 800–900.
   - It increases slightly for Dentist 5.

2. **Method 2 (Orange)**:
    - This method starts at the highest hardness (around 950 for Dentist 1) and gradually decreases across dentists. However, it stabilizes around 800 after Dentist 3, with minor fluctuations.
3. **Method 3 (Green)**:
    - Method 3 shows the most variability, similar to the previous alloy plot. It starts lower than other methods, at around 700, and dramatically declines after Dentist 3. By Dentist 5, it reaches the lowest hardness (~450).

Conclusion:

- Method 1 is relatively consistent, while Method 2 shows a steady decline but remains stable across most dentists.
- Method 3 shows a strong interaction with the dentists, particularly declining significantly after Dentist 3.
- There is clear evidence of interaction between dentists and methods, with Method 3 particularly sensitive to changes in dentists, resulting in large variations in hardness.

-4.4 Combined Effects of Dentists and Methods:

Objective:

To determine whether the Response of dental implants varies significantly based on the combination of dentists and methods used. Additionally, this study examines whether the interaction between dentists and methods influences implant Response.

State the Null and Alternate Hypotheses

- **Null Hypothesis (H_0)**: There is no significant interaction effect between dentists and methods on the Response of dental implants.
- **Alternate Hypothesis (H_1)**: There is a significant interaction effect between dentists and methods on the Response of dental implants.

Test Used: Two-way ANOVA

Assumption:

1.Normality:

- The sample data for Methods and their responses consists of a large sample size, typically greater than 30 ($n > 30$). According to the Central Limit Theorem, when the sample size is sufficiently large, the distribution of the sample means will approximate a normal distribution, regardless of the original distribution of the population. Therefore, we can reasonably assume that the data is normally distributed.

2.Homogeneity of Variances:

Null hypothesis (H_0): The variances are equal (homogeneity of variances).

Alternate hypothesis (H_1): The variances are not equal (heterogeneity of variances).

Proceeding with the Assumption of no significant difference, we fail to reject the null hypothesis.

3.Independence:

- Observations are independent of each other. Since each measurement is taken independently, this assumption is satisfied.

Table 6. ANOVA Results for Combined Effects of Dentists and Methods:

Source	df	Sum of Squares	Mean Square	F-statistic	p-value
C(Dentist)	4	1,57,794.56	39,448.64	3.55	0.01
C(Method)	2	5,93,427.49	2,96,713.74	26.702	0
C(Dentist):C(Method)	8	306471.84	38,308.98	3.448	0.002
Residual	75	8,33,401.67	11,112.02	NaN	NaN

Interpretation:

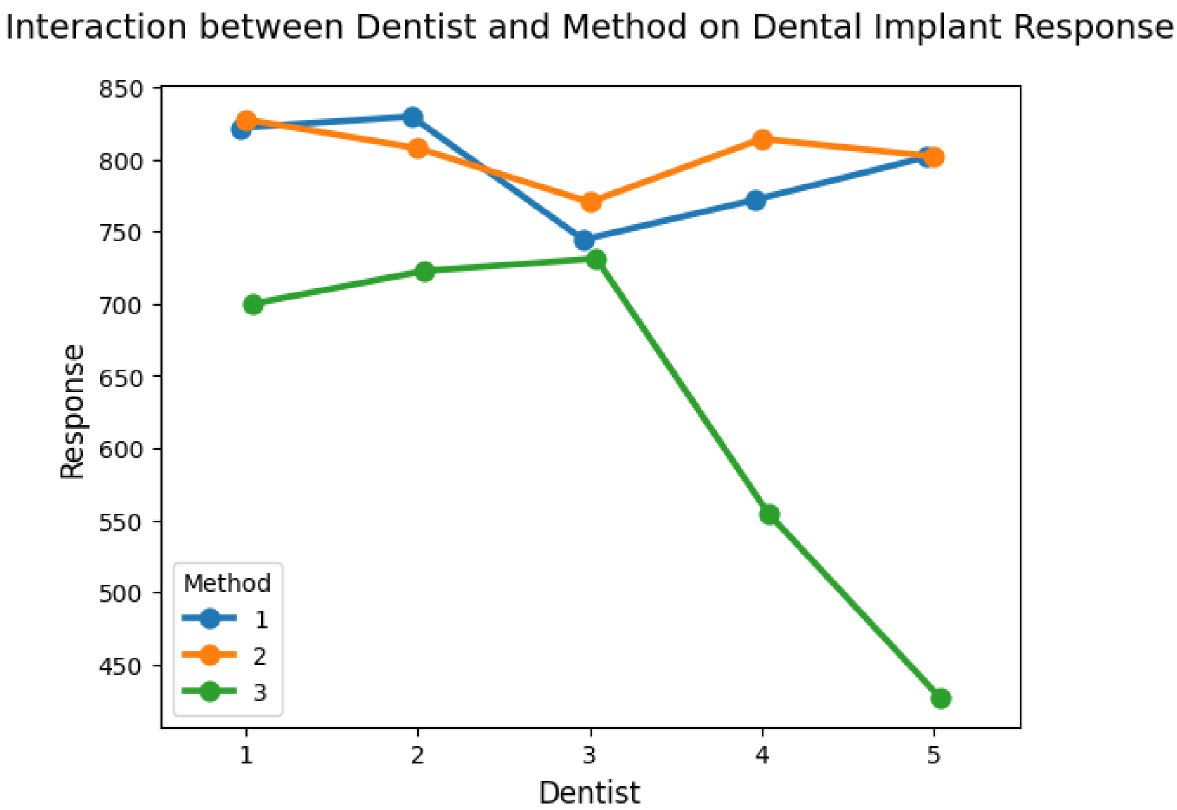
Dentist effect: The p-value for the dentist effect is 0.010, which is less than 0.05. This indicates that the dentist performing the procedure significantly affects the Response of the implants.

Method effect: The p-value for the method effect is less than 0.001, showing that the method used is highly significant in influencing implant Response.

Interaction effect: The interaction between dentists and methods has a p-value of 0.002, meaning that there is a statistically significant interaction between the two factors. Thus, the effect of the method on Response depends on the dentist performing the procedure.

Conclusion: We reject the null hypothesis for dentists ($p = 0.010$), methods ($p < 0.001$), and their interaction ($p = 0.002$) which is less than 0.05(alpha). This confirms that implant Response significantly varies based on the dentist, the method, and their combination.

Figure 11. Interaction between Dentist and Method on Dental Implant Response



Interpretation :

This plot shows the interaction effect between dentists and methods on the dental implant response, representing hardness across different combinations of dentists and methods.

Key observations:

1. **Method 1 (Blue)**:
    - The response is relatively stable across most dentists, with a peak response for Dentist 2 (around 850) and a slight dip for Dentist 3 and Dentist 5. This indicates that Method 1 yields consistent performance with some variability across dentists.
2. **Method 2 (Orange)**:
    - Method 2 starts with the highest response for Dentist 1 (around 825) and fluctuates slightly for the other dentists. The trend remains relatively stable but lower compared to Method 1 by the end of the graph.

3. **Method 3 (Green)**:
    - This method starts at a lower response level (~700) and shows a gradual decline across dentists, with a sharp drop after Dentist 3. By Dentist 5, it has the lowest response, close to 450. This suggests Method 3 may be less effective overall and particularly sensitive to variations between dentists.

Conclusion:

- There is a significant interaction between dentists and methods in determining the dental implant response.
- Method 1 is the most stable, while Method 3 shows a marked decline in response, particularly after Dentist 3, indicating a strong dentist-method interaction for this method.
- Overall, the variability across dentists is more pronounced for Method 3 compared to Method 1 and Method 2.

post-Hoc Analysis (Tukey's HSD Test)

- The Tukey's test revealed which specific combinations of dentist and method resulted in significantly different implant Response.
- Several comparisons showed significant differences, such as:
    - Dentist 1, Method 1 vs. Dentist 4, Method 3 (p=0.0031p = 0.0031p=0.0031)
    - Dentist 1, Method 1 vs. Dentist 5, Method 3 (p=0.0p = 0.0p=0.0)
    - Dentist 4, Method 1 vs. Dentist 5, Method 3 (p=0.0096p = 0.0096p=0.0096)

These results suggest that certain dentist-method combinations produce substantially different results in implant Response, with some combinations significantly outperforming others.

Conclusion: The analysis provides strong evidence that both the dentist and the method used in the procedure significantly impact the Response of implants. Furthermore, the interaction between the two factors plays a critical role in determining the outcome. Post-hoc analysis shows that specific dentist-method combinations are more effective, implying that clinics should consider these factors when planning procedures to optimize results.

3. Conclusion and Recommendations:

3.1.Conclusion:

This report has explored four distinct problems using inferential statistical techniques to derive meaningful insights across various domains—sports management, manufacturing, and dental practices.

1. **Player Injuries and Positions (Problem 1)**
   The analysis revealed that player positions influence the likelihood of foot injuries, with strikers and forwards having higher injury risks compared to other positions. These findings can guide physiotherapists and coaching staff in implementing tailored preventive measures for high-risk players, enhancing player safety and team performance.
2. **Breaking Strength of Gunny Bags (Problem 2)**
   The study of gunny bags used for cement packaging showed that the breaking strength follows a normal distribution. The analysis identified proportions of bags that do not meet the required strength, highlighting areas for improvement in quality control and ensuring product reliability in the supply chain.
3. **Stone Hardness for Printing (Problem 3)**
   Hypothesis testing on the hardness of stones used for printing confirmed that unpolished stones may not meet the required hardness standards. The comparison between polished and unpolished stones provided evidence of significant differences in their suitability for printing, suggesting that Zingaro Stone Printing should focus on processing stones to achieve the desired hardness levels.
4. **Response of Dental Implants (Problem 4)**
   The investigation into dental implant responses demonstrated that both the method of implantation and the dentist’s approach significantly affect the hardness of implants. Additionally, interaction effects between these variables were found, emphasizing the need for optimizing implant techniques and materials. This finding is crucial for improving dental implant outcomes and enhancing patient care.

3.2.Final Recommendations:

Across these four problems, the use of statistical analysis has provided actionable insights:

- In sports management, a focus on injury prevention strategies tailored to player positions can improve player safety.
- In manufacturing, quality control measures should be strengthened to ensure product durability.
- For stone printing, polished stones should be prioritized to meet quality standards.
- In dental practices, selecting the right combination of implant methods and training for dentists can significantly improve patient outcomes.