Study on Mechanical Behaviour of PEEK Biomaterials Compared with SS316L in Medical Development & Environment

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Abstract: - The selection of an appropriate biomaterial plays a significant role in improving the performance and longevity of medical implants. Polyetheretherketone (PEEK), 30% glass fiber reinforced PEEK (PEEK 30% GF), and SS316L stainless steel were comparatively evaluated to determine their suitability for long-term orthopedic applications. Wear experiments were conducted under identical testing conditions by measuring wear depth, frictional force, coefficient of friction, and weight loss. The age-dependent mechanical properties of human bone were also considered to assess the compatibility of these materials with natural bone behaviour. The experimental results revealed that PEEK exhibited the lowest wear, minimum weight loss, and superior tribological performance. PEEK 30% GF provided enhanced mechanical strength with satisfactory wear resistance, whereas SS316L showed the highest material loss and comparatively poorer wear performance. Overall, the findings demonstrate that PEEK-based biomaterials provide improved durability and mechanical compatibility, making them promising candidates for future orthopedic and spinal implant applications.

Key-Words: - SS316L, Implant materials, Wear analysis, PEEK, Polymer, Biomaterials, Biocompatibility.

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1 Introduction

The Biomaterials widely rely on biomaterials for the replacement of weakened bones and weakened body tissues which are weakened. The SS316L stainless steel is the most commonly used metallic implant material due to its high mechanical strength, impressive corrosion resistance and good biocompatibility, [1]. Though it has favourable mechanical properties, its high stiffness in comparison with bone will cause stress shielding, due to which the load transfer to the surrounding bone reduces this phenomenon eventually affects the implant stability in its prolonged usage. In recent years, polyetheretherketone (PEEK) has emerged as a promising and most reliable alternative biomaterial because of its low density, good chemical stability, corrosion resistance and better mechanical properties has made it closest to human bone hence PEEK is significant. Further, reinforcement grades like PEEK with 30% glass fiber (GF) offers a enhanced stiffness and strength which makes most suitable material.

Earlier studies have reported that PEEK has captured interest due to its lower elastic modulus, lightweight nature, and satisfactory biocompatibility [1], [2], while SS316L is extensively used in orthopedic implants because of its good mechanical strength and better corrosion resistance, [3]. PEEK reinforcement grades like PEEK with 30% GF have also been inspected for improved stiffness and strength in load-bearing applications. However, previous works focused on these materials individually, and a direct comparison of PEEK, PEEK 30% GF, and SS316L under similar wear testing conditions is still restricted. This has led to a research gap in grasping their tribological performance for various implant applications. Setting strength apart, the durability of the performance of implant materials highly depends on their wear characteristics, particularly frictional characteristics because excessive wear may give rise to fragments which can cause inflammation, damage the bone, loosen the implants and eventually can cause failure, [4]. The present study mainly emphasizes this gap through direct experimental comparison by conducting tribological tests on wear depth, frictional force, coefficient of friction, and weight loss behaviour. The novelty of the present study lies in the direct experimental comparison of PEEK, PEEK 30% GF, and SS316L under the identical wear test conditions, while keeping focus on tribological performance and material long-term usage. The outcomes of this research are used to support the selection of upgraded biomaterials for upcoming orthopedic implant development in the field of materials.

2 Implants

The compatibility of implant materials refers to the overall relevance of a material for contact with the human body and its bones and tissues, [4]. This concept encompasses the material's capacity to function effectively in a specific medical environment, while producing a biological response in the body, which can be highly dependent on the intended applications and suitable environmental conditions A material is considered suitable for a particular implant application when it supports normal body function without causing the complications or any other issues such as allergic reactions, inflammation, in the body or other harmful effects. The composition, microstructure, and tensile properties of titanium, cobalt chrome, zirconium, stainless steel, and titanium alloys used for internal fixation are standardized in IS and ASTM specifications, [5], [6], [7]. This should not be confused with sterility. Sterility only means treating a material to remove all living microorganisms, including resistant bacterial or fungal spores, and does not itself indicate suitability for implantation. An implant is a medical device designed to remain in the body, and failure occurs when it produces unwanted effects such as pain, infection, toxicity, or excessive surface damage that may finally lead to rejection. An implant is considered failed when it no longer performs the function for which it was inserted. This may happen for several reasons, including wear and material degradation during service. The suitability of high-quality stainless-steel implants has been proven through decades of successful human use. The composition, microstructure, and tensile properties of titanium, cobalt chrome, zirconium, stainless steel, and titanium alloys used for internal fixation are standardized in IS and ASTM specifications. Metallurgical requirements remain strict to ensure good corrosion resistance [7], low magnetic response, and dependable mechanical properties. The torsional behavior of stainless steel screws differs from that of titanium screws. Stainless steel bone screws are easier to handle because surgeons can feel the beginning of plastic deformation, giving an early warning to avoid over-torquing the screw, [8]. As shown in Figure 1, the primary requirements of biomedical implants include compatibility, mechanical properties, and manufacturing characteristics. These factors play a vital role in determining the performance, reliability, and long-term success of implant materials.

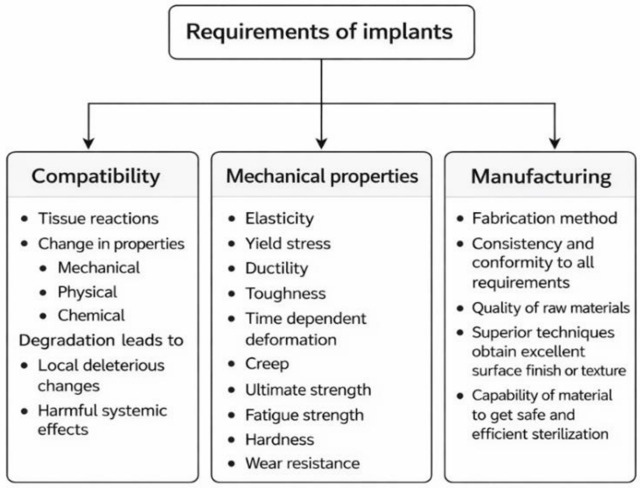

Fig. 1: Implant Process flow chart
Source: Created by authors

3 Polymer Materials

Polymer materials, particularly the material called polyetheretherketone (PEEK) have become highly important materials for advanced applications in implants due to their lightweight and also very flexible in nature and excellent compatibility with biological interaction with bones and tissues. PEEK demonstrates strong mechanical properties, chemical stability and also high corrosion resistance, which makes it suitable for long-term use in the medical field, [9], [10]. Its stiffening in the bone helps in facilitating effective load transfer and reduces the risk of implant-related complications. Furthermore, the less dense area PEEK makes post-operative scans clear and free from errors if any, thereby improving the clinical evaluation making it easy after the implants. The materials of wear resistance, durability, and low moisture absorption further contribute to its reliability in challenging biomedical environments, [11], [12]. Although untreated PEEK is relatively bioinert, surface modification methods and composite reinforcement have been indicated to improve bone bonding and cell response. Collectively, this much of advantages have made increasing use of PEEK-based polymer biomaterials

4 Bone

Bone is a living connective tissue that provides structural support, protects vital organs, and facilitates movement in the body with muscles. Its composition imparts strength, toughness, and the ability to remodel throughout life. For optimal implant performance, biomaterials should closely resemble bone in both mechanical and biological properties. The very important factors include compatibility in stiffness, strength, biocompatibility, and corrosion resistance. Polyether ether ketone (PEEK) is widely considered an appropriate implant biomaterial due to its mechanical properties, which more closely match those of natural bone compared to metallic alternatives like SS316L.

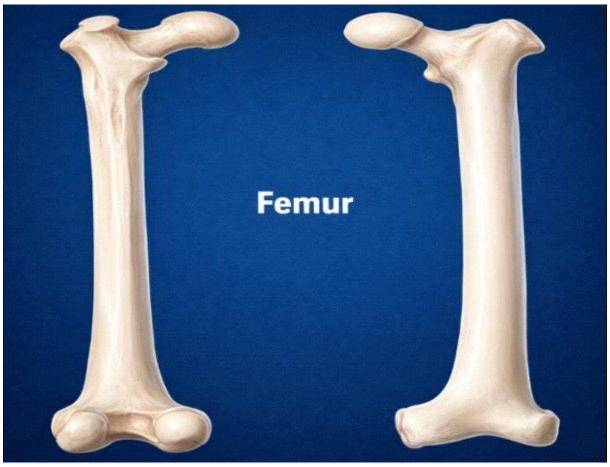

Fig. 2**:** Femur Bone
Source: Created by authors

However, pure PEEK is biologically inert and may demonstrate limited direct bone bonding. To address this limitation, glass fiber-reinforced PEEK (PEEK 30% GF) offers improved stiffness and strength, making it suitable for load-bearing orthopaedic applications and maintaining favourable imaging characteristics, [13]. In contrast, SS316L stainless steel provides high strength, durability, and corrosion resistance, but its much greater stiffness relative to bone can increase stress shielding. Therefore, as shown in Figure 2**,** the selection among PEEK, PEEK 30% GF, and SS316L depends on mechanical compatibility with bone, [14].

4.1 Analysis of Mechanical Properties of Bone

In the ages of 10 and 80 years, the strength of bones does not always stay the same, and tension, compression, bending and torsion changes take place due to the structural changes within the body. The above analysis of the mechanical behaviour of bone and the percentage of elongation of the bone, which represents the various mechanical properties, is done by taking into consideration the different ages, [13]. The characteristics of any material are defined by its chemical composition, as well as intermolecular forces, which determine its molecular structure. This macromolecular structure has a direct effect on behaviour and ultimately controls the interaction of the material at its interface with blood or in the bones. These age-related changes affect the ultimate strength and ultimate strain of bone under different loading conditions Table 1 (Appendix) shows the variation in the ultimate strength and ultimate strain of bone under tension, compression, bending, and torsion across different age groups, [14].

The properties of bone related to bone strength, which varies with age. It can be observed that the mechanical strength of bone gradually decreases as age increases, resulting in reduced load-bearing capability. And it is clearly shown in the Table 1 (Appendix). This reduction in strength highlights the need for suitable biomaterials, such as polymer-based materials, for orthopedic and biomedical applications.

5 Overview of Bone Properties by Age

5.1 Torsion Strength at Different Ages

The torsion values of bone across different age groups from 10 to 70 years are presented, as shown in Table 2**.** At the age of 10, the torsion strength is 58. The maximum Torsion values are at ages 20 and 30, with a value of 57. It slightly reduces to 52 at the ages of 40 and 50. This also continues to drop from 49 at the age of 60 and 70. In outline, the base truth that gives the torsion strength will not change during the beginning stages of adulthood but reduces with age, [15]. This indicates a reduction in the bone resistance to rotating forces as people age, as shown in Figure 3. This data can be used to develop age-specific orthopedic treatments and early care.

Table 2. Effect of age on Torsion Strength

Age (Years)	Torsion
10	58
20	57
30	57
40	52
50	52
60	49
70	49

Source: Created by authors

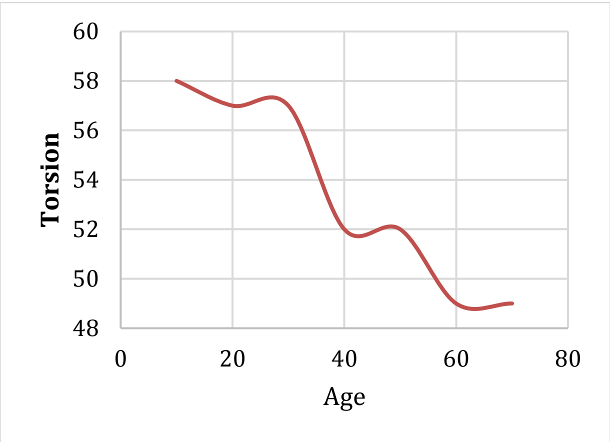

Fig. 3: Torsion Strength of bone with Age
Source: Created by authors

As shown in the Figure 3 torsion strength shows that the torsion values vary within a range on the x-axis between 0 and 100. The y-axis is the torsion values, between 48 and 58. At first, the torsion value is approximately 57, and it is constant for a small period, after this it decreases sharply between x = 20 and x = 40, showing a fast decrease in torsion. There is a short stable phase or slight rise around x = 45 and then another sharp decline till approximately x = 60. Following this, the torsion value becomes steady around 49. The general progress is that the torsion reduces drastically with an increase in the x-axis variable, [15]. The graph has a smooth, curved appearance, suggesting gradual changes between the points. This graph is applicable in mechanical studies of torsional behavior with time.

The bar chart of Torsion Strength of Bone depending on age shows the correlation between age (in years) and torsion strength. The age is shown as brown bars, and torsion strength as purple bars as show in Figure 4. In between ages of 10 and 30, there is a yet steady, decrease in torsion strength from 57 to 52. However, the age is still increasing, torsion strength levels off at 52 between the ages of 30 and 50. After age 50, torsion strength starts decreasing more rapidly, to 49 at age 70. The graph is a good display of the inverse connection between the torsional strength of bones and age, [14], [15].

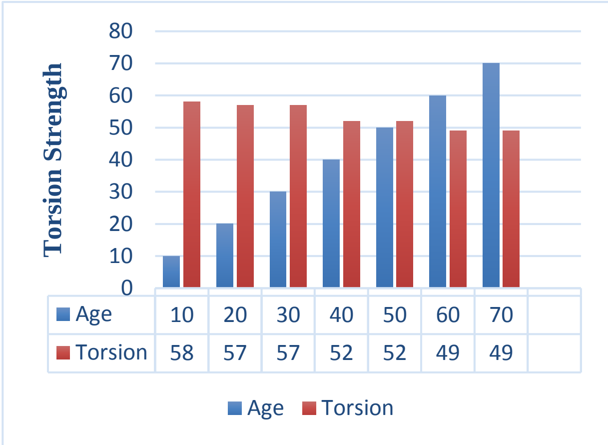

Fig. 4: Variation in Torsion Strength with Age
Source: Created by authors

5.2 Tensile Strength at Different Ages

Table 3. Effect of Age on Tensile Strength

Age(Years)	Tensile
10	114
20	123
30	120
40	112
50	93
60	86
70	86
80	75

Source: Created by authors

In the Table 3 It shows the variation in the Tensile strength corresponding to age, between the ages of 10 and 20, tensile strength increases between 114 and 123, with good performance at 20 years old [15]. Then slightly reduces to 120 at age 30 after to 112 at age 40, as shown in Table 3**.** This reduction trend persists considerably, to 93 at the age of 50 and even more at the age of 60 and 70 [16]. The tensile strength seems to be constant at age 60-70 at 86. Age 80 data is 75, which may give additional details about the later stage behavior.

The tensile strength will increase first in the range of 114 to a maximum of 123 at age 20, it means the material is at its optimum resistance. The gradual reduction starts after age 20, and reaches 120 at age 30 and 112 at age 40, as shown in Figure 5. There is a sharper reduction after 40 and the values are 93 at age 50 and 86 at age 60 and 70 [19]. This tells that there is a high correlation between tensile strength decrease and aging. The information shows the significance of observing the material or biological performance with in the time. The curve offers a graphic representation of structural decline over age, this can be used in material studies and in future research.

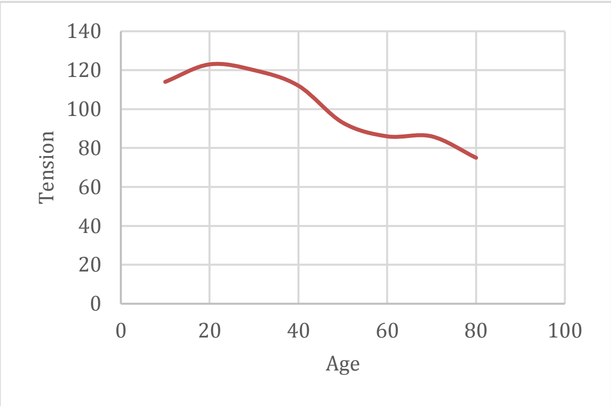

Fig. 5: Tension Strength of bone with Age
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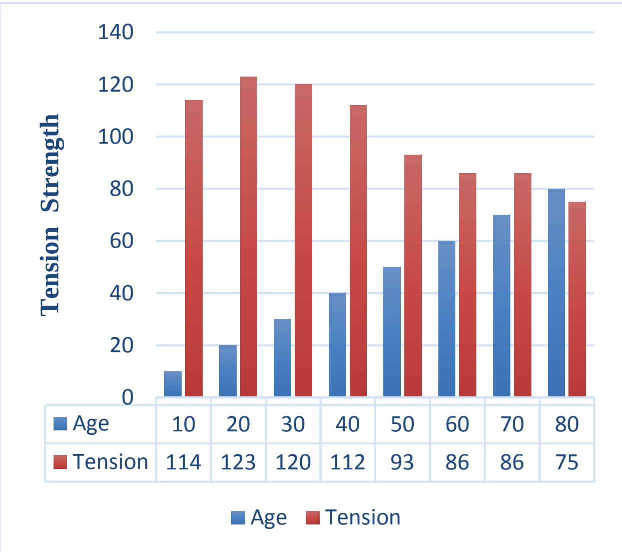

Fig. 6: Variation in Tension Strength with Age
Source: Created by authors

As shown in the Figure 6 the connection that exists between age and tensile strength. The tensile strength is shown by the red bars and the age groups between 10-80 years are depicted by the blue bars, as shown in Figure 6. The tensile strength rises to a peak of 123 at the age of 20, which means that the bone is at its optimum resistance in early adulthood. After the age of 30 [17], there is a gradual decrease to 86 at age 70 and the same at age 80. This loss is an indication of the normal decline of bone quality with age. The decreased tensile strength with increased age suggests that bone has lower resistance to pulling forces. The graphical analysis shows the relationship between tensile strength and age. These insights are crucial in understanding age related bone weakening and developing preventive healthcare strategies. The information is very beneficial when designing implants and fixation devices that are age specific. It also helps in the choice of biomaterials that have mechanical properties that are more similar to natural bone behaviour. This indicates the overall performance of the tensile strength with age that gradually increase in indicates the quality of the age of the bone. This clearly tells how this effects the tension strength by age and the importance of mechanical property which is related to bone is been very important when considering implant in the field of medical and also in the material science.

5.3 Bending Strength at Different Ages

Table 4. Effect of Age on Bending Strength

Age(Years)	Bending
10	151
20	173
30	162
40	154
50	139
60	139
70	138
80	130

Source: Created by authors

The Table 4 shows the bending values of different age groups (10-80 years). It shows that the value of bending goes up to 151 at the age of 10 and then rises at 173 when one is 20 years old, as shown in Table 4. Following this rise in this is a gradual decrease with values of 162 at age 30, 154 at age 40 and 139 at age 50 and 60. The graph then exhibits a steep and steady decrease after this point. At x = 60, the compression strength has decreased greatly to about 145. However, data for the age groups 70 and 80 bending strength is 138 and 130. Usually, the findings suggest that the strength of bending is enhanced until early adulthood and gradually reduces with age.

The bending strength changes in a range of values on the x-axis (0 to 100). The bending strength starts at about 155 and reaches its maximum of about 175, as shown in Figure 7. Once this rises obtained, the strength is slowly reduced with a low slope. The bending strength reduces to about 135 by the x-axis value of about 60. The general tendency is an upward trend with a gradual decrease.

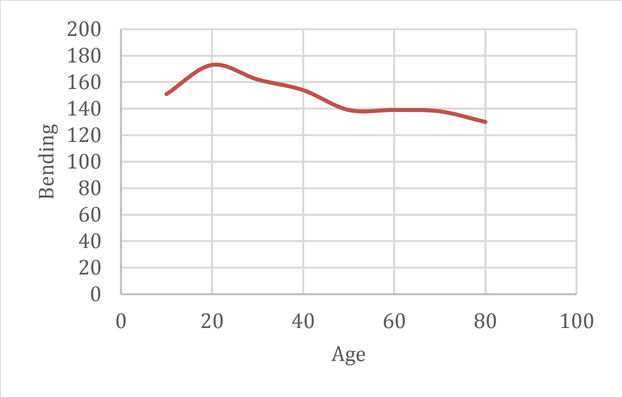

Fig. 7: Bending Strength of bone with Age
Source: Created by authors

This trend can be an indicator of initial strengthening and then material fatigue or aging, [17]. The graph emphasizes the age-related alterations in the bone density and internal structure and their impact on bending strength. The decrease following the peak indicates that the older age groups have less resistance to bending loads. The indication is relevant in the context of the fracture risk and the choice of appropriate biomaterials to apply in the cases of age-specific implants. The findings also highlight the need to take into account age-related mechanical behaviour in the design of orthopaedic implants.

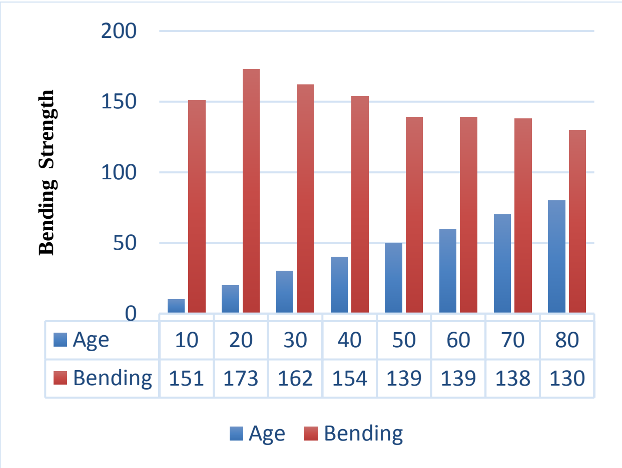

Fig. 8: Variation in Bending Strength with Age
Source: Created by authors

The bending strength with age between the ages of 10–80 years. It starts at age 10 with 15and reaches its highest point of 173 units at age 20, as shown in Figure 8**,** which means that the bending capacity is the highest at the early adulthood stage. After this rise, the bending strength gradually reduces with increasing age. At age 30 it is 162, then decreases to 154 at age 40 and 139 at age 50. Between 60 and 70, there is a very slight variation in the values, which are approximately 138-139. At 80, the bending strength is further decreased to 130, indicating that there is a definite decline in strength as age increases.

5.4 Compression Strength at Different Ages

Table 5. Effect of Age on Compression Strength

Age(Years)	Compression
10	166
20	167
30	167
40	161
50	155
60	145
70	132
80	117

Source: Created by authors

Table 5 shows compression values of bone in various age groups ranging from 10 to 80 years. Data for age 10 is 166 for compression strength. Although the ages 20 and 30 have the highest compression value of 167, as shown in Table 5. The compression strength gradually decreases with age, to 161 at age 40, 155 at age 50, and 145 at age 60, [17]. The age 70 and 80 data are unavailable. In general, this shows that bone compression strength decreases with age after early adulthood. This suggests that there is a weakening of bone structure with age. More research is required to determine the strength of compression among the elderly. These are relevant in the prevention of bone fractures in old age.

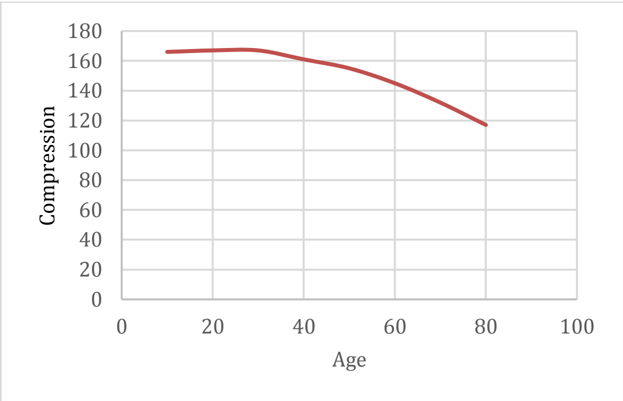

Fig. 9: Compression Strength of bone with Age
Source: Created by authors

The compression strength varies on the x-axis (0 to 100), at the beginning, compression strength is approximately 167 and is relatively constant till the x-axis of 30, as shown in Figure 9. The graph then exhibits a steep and steady decrease after this point. At x = 60, the compression strength has decreased greatly to about 145 [13], [18]. The curve shows that the trend is very negative after the first stage. This implies a material or structural degradation with compressive forces over time or condition. The graph is useful in showing the critical decline zone, which is of relevance in mechanical and materials properties.

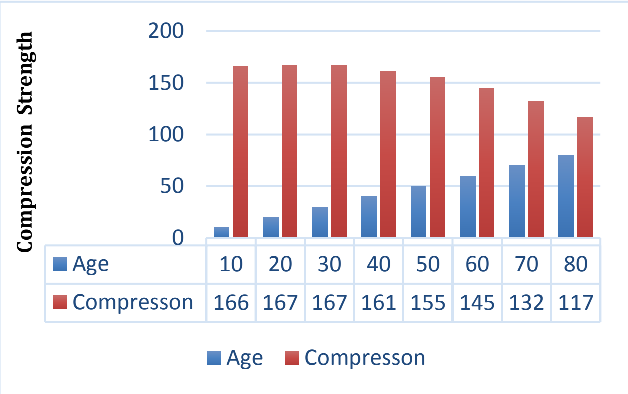

Fig. 10: Variation in Compression Strength with Age
Source: Created by authors

The graph with Compression Strength of Bone depending on Age shows a comparison of bone strength of different age groups. The green bars show the strength of compression and the dark brown bars represent the years of age, as shown in Figure 10**.** The compression strength is stable between the ages of 10 and 30 at 167, showing the maximum bone obstruction in young people. With the increase in age (40 to 70), a progressive decrease in strength is observed- 161 to 145, which is an indicator of age effect, [19]. The most drastic decrease is between 50 and 70 years. Surprisingly, the age is on a steady rise, but beyond 30, compression strength starts to decline drastically.

6 Wear on Polymer Materials

Wear in polymer materials can be defined as the gradual loss or destruction of the surface of the polymer during mechanical contact, e.g. sliding, rolling, or repeated impact, [5], [20]. Polymers exhibits wear behaviour unlike other metals because of their stress responsive nature and is usually affected by adhesive, abrasive, fatigue, and corrosive processes. Adhesive wear is due to contact of the surface and transfer of material whereas abrasive wear is due to hard particles scratching the surface. The cyclic loading may cause fatigue wear due to crack formation and environmental conditions including temperature, humidity and chemical exposure can also accelerate the wear rate [6]. Polymers wear performance is influenced by the load, sliding velocity and counter surface conditions. Surface coatings, fillers such as glass or carbon fibers, and others are frequently added to enhance their durability, [20]. UHMWPE, and PEEK are popular materials used in biomedical and engineering applications due to their low friction, chemical stability, and wear resistance, [21]. Hence, polymer wear behaviour is significant in the selection of reliable materials and enhancement of service life and safety of parts in various industries, [21].

7 Mechanical Properties Comparison of Selected Materials

In the present study, which includes Stainless Steel 316 (SS316L), Polyetheretherketone (PEEK) and Polyetheretherketone reinforced with 30% glass fiber (PEEK 30% GF). The choice of these materials was based on how widely they are used in biomedical, structural, and industrial settings because of their unique physical and mechanical properties [4], [15], as shown in Table 6**.** SS316L stainless steel is an austenitic biomaterial which is commonly used in implants and surgical equipment due to its high mechanical strength, Good corrosion resistance and excellent biocompatibility, making it suitable for long-term biomedical applications.

Table 6. Properties of SS316L, PEEK, PEEK 30% GF

Materials	Density (g/cm3)	Tensile Strength ultimate (MPa)	Modulus of elasticity (Gpa)
SS316L	7.85	510-620	190
PEEK	1.32	90-100	3.6
PEEK 30% GF	1.52	190	12

Source: Created by authors

It has a comparatively high density, which provides structural rigidity and strong load-bearing capability. Moreover, it is very stiff and strong in tensile strength, which makes it very dependable in its use in applications that demand stability of dimensions under the influence of mechanical forces, [22], [23]. PEEK is a thermoplastic polymer of high performance, which has acquired significant significance in the orthopaedic, spinal and dental implants due to its chemical stability, light weight and great compatibility with body tissues, [24], [25].

PEEK has lower density and higher flexibility than metallic biomaterials, yet is strong enough to be used in most biomedical applications. It is also bone-like in its stiffness and prevents stress shielding as well as enhances load sharing in implant systems, [26]. PEEK with 30 percent glass fiber reinforcement is a new composite that has been created to enhance the mechanical characteristics of pure PEEK. The glass fiber reinforcement makes it a little denser but much more tensile strength and stiffness, [27], [28]. This enhancement renders the composite more applicable in the challenging implant cases where greater strength, dimensional stability, and structural integrity are demanded.

8 Results and Analysis

8.1 Regression Analysis of Age-Dependent Bending Strength

A quadratic polynomial regression model was fitted using the bending strength data in Table 4 to make the mathematical analysis of the experimental observations stronger. The regression equation that was found is:

$$y = -0.00536x^2 - 0.00119x + 161.96$$

where x is the person's age in years, and y is their bending strength. For instance, at the age of 50:

$$y = -0.00536 \times (50)^2 - 0.00119 \times (50) + 161.96$$

$$y = -13.40 - 0.059 + 161.96y = 148.50$$

The experimental value at age 50 is 139**,** while the expected value is 148.50, showing good Consistent with the measured trend. The fitted model's coefficient of determination is $R^2 = 0.709$, which means that the regression model explains 70.9% of the difference in bending strength with age and demonstrates good predictive capability, as shown in Figure 11**.**

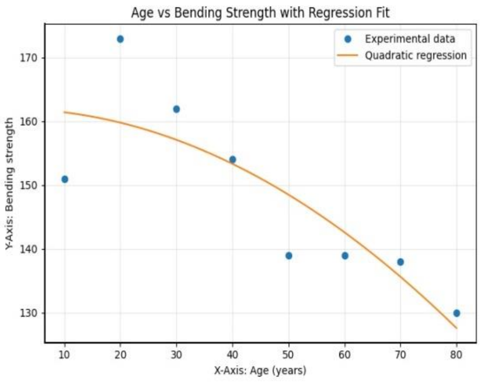

Fig. 11: Regression analysis of age-dependent bending strength with X-axis and Y-axis representation
Source: Created by authors

8.2 Archard Wear Equation Analysis of Selected Biomaterials

The wear test results of PEEK, PEEK 30% GF, and SS316L showed clear differences in tribological performance.
The wear behaviour of the tested materials was further analyzed using the Archard wear equation:

$$W = KLS / H$$

where W is the wear loss, K is the wear coefficient, L is the applied load, S is the sliding distance and H is the hardness of the material. Based on the experimental wear data from Table 8, the comparative wear ratio was calculated by taking PEEK as the reference material.

For PEEK 30% GF:

$$\text{Wear ratio} = 450 / 220 = 2.05$$

This shows that PEEK 30% GF has 2.05 times higher wear than pure PEEK.

For SS316L:

$$\text{Wear ratio} = 2005 / 220 = 9.11$$

This indicates that SS316L shows 9.11 times higher wear than pure PEEK under the same test conditions. The above calculations tell about the best wear resistance for the tribological performance of pure PEEK compared with PEEK 30% GF and SS316L.

8.3 Evaluation of Weight Loss Due to Wear

The Table 7 (Appendix) shows the initial weight, final weight, and weight loss of PEEK, PEEK 30% GF, and SS316L at the end of the wear test. PEEK 30% GF had the lowest weight loss, 0.00213 g, indicating outstanding wear resistance under the chosen conditions, as shown in Table 7**.** Very low weight loss of 0.00366 g was also observed in pure PEEK and this confirms its good tribological behaviour and its suitability in biomedical implant applications. In contrast, SS316L gives a much greater loss of weight of 0.42936 g, indicating considerable material loss during sliding. The results clearly give that PEEK-based materials provide much better wear resistance and durability compared with SS316L.

The results indicate that PEEK exhibited the best overall wear and friction behaviour, followed by PEEK 30% GF, while SS316L showed the poorest wear performance under identical conditions in the medical applications, as shown in Figure 12**.** The minimum weight loss in the PEEK and PEEK30%GF provides excellent wear resistance, whereas the considerably higher loss in SS316L indicates extreme wear during sliding. These results confirm that PEEK-Based materials are more suitable for medical applications requiring low wear, and reliable for long term performance of mechanical properties, which gives the maximum performance in the medical applications the poorest wear material will always have an effect on any medical applications for long durability for consideration in this field so this will be carefully analyzed and taken in to consideration.

8.4 Tribological Performance Analysis of Selected Materials

The graph is used to compare the rate of weight loss of PEEK, PEEK 30% GF and SS316L in the same test conditions. The greatest weight loss is shown in SS316L, representing the maximum material removal of the samples tested [15]. PEEK 30% GF displays a medium weight loss, which is moderate compared to pure PEEK but significantly less than SS316L, indicating that glass fiber reinforcement increases wear resistance without yet reducing the unfilled PEEK. PEEK exhibits the minimum weight loss of all the materials, and this proves that it has the best wear resistance. In general, it shows that PEEK is the best material when it comes to minimum wear and best durability then PEEK 30% GF, and SS316L presents relatively poor wear behaviour in the same conditions.

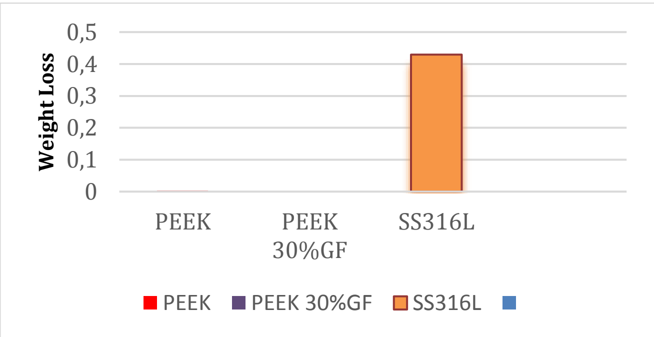

Fig. 12: Weight Loss rate of selected materials
Source: Created by authors

Table 8. Tribological Properties of PEEK, PEEK 30% GF, and SS316L Materials

Materials	Wear (µm)	Frictional force (N)	Coefficient of Friction
PEEK	220	12	0.300
PEEK 30%GF	450	30.4	0.760
SS316L	2005	18.6	0.465

Source: Created by authors

A comparison between the wear and friction behaviour of PEEK, PEEK 30% GF and SS316L is show in the Table 8 PEEK is the least worn material and has a low coefficient of friction among the tested materials, which indicates that it shows high tribological performance. PEEK 30% GF has the maximum wear and the highest value of friction, which is primarily due to the fact that the glass fibers added to the material, add to the contact of the surface during sliding. Even though SS316L has a moderate value in terms of friction, it is the one that shows the greatest wear, which implies that it is less suitable for work where the contact with the surface is repeated. These findings also justify the application of PEEK in biomedical devices like joint and spinal implants, where wear debris is of concern in the long-term biocompatibility and life of implants. PEEK 30% GF may still be applicable in the use where the strength is a more significant factor than the friction behaviour. Further coating or surface modifications could be necessary in the case of SS316L to enhance wear resistance in harsh tribological environments.

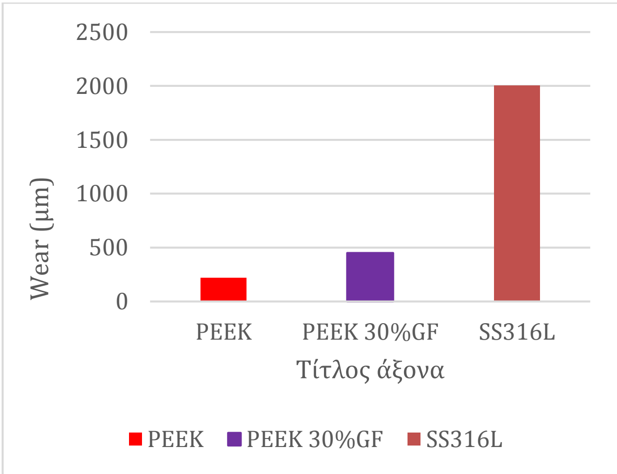

Fig. 13: Wear Analysis (µm)
Source: Created by authors

The wear analysis graph shows that the wear value of PEEK is the minimum, and also proves the highest wear resistance of all the selected materials, as shown in Figure 13. PEEK 30% GF exhibits a minimum wear, whereas SS316L has the largest wear and the greatest material loss under the same conditions. This trend is also supported by the weight loss results, where PEEK-based materials exhibit little material loss and enhanced durability. In general, PEEK and PEEK 30% GF are better to use in long-term biomedical implants, and also SS316L requires surface treatment to give better wear resistance.

9 Conclusion

This study compared the wear and mechanical performance of PEEK, PEEK 30% GF, and SS316L for biomedical implants. The results showed that PEEK provided the best wear resistance and tribological performance, making it highly suitable for orthopaedic and spinal applications. PEEK 30% GF offered improved strength with slightly higher wear, while still performing much better than SS316L. In contrast, SS316L showed the highest wear and material loss, indicating lower suitability for repeated sliding applications. Overall, the findings confirm that PEEK-based biomaterials are more promising than conventional metallic materials for future implant applications. Further work can focus on toxicity evaluation of the materials to confirm their long-term biological safety and implant compatibility**.**

Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work the authors used Grammary for language editing. After using this service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication

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APPENDIX

Table 1. Strength of Bone according to Age

Age (Years)							
Property	10-20	20-30	30-40	40-50	50-60	60-70	70-80
Ultimate Strength (MPA) Tensile Strength							
Tension	114	123	120	112	93	86	75
Compression	116	167	167	161	155	145	117
Bending	151	173	173	162	154	139	139
Torsion	58	57	57	52	52	49	49
Ultimate Strain (%) – Percentage of Elongation at Break							
Tension	1.5	1.4	1.4	1.3	1.3	1.3	1.3
Compression	2.0	1.9	1.8	1.8	1.8	1.8	1.7
Bending	1.7	1.8	1.8	1.7	1.6	1.6	1.5
Torsion	2.9	2.8	2.8	2.5	2.5	2.7	2.7

Source: Created by authors

Table 7. Weight Loss Analysis of Materials

Materials	Initial Weight (gm)	Final Weight (gm)	Weight Loss (gm)
PEEK	3.28463	3.28087	0.00366
PEEK 30%GF	6.70263	6.70050	0.00213
SS316L	7.12291	6.69361	0.42936

Source: Created by authors

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Conflict of Interest

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