Original Article

Preparation And Characterization Of A Novel Natural Fiber Based Composite For Dental Implants

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Abstract

This paper presents the fabrication and characterization of a composite material made with natural fibers namely Kenaf, Pine apple, and jute fibre in epoxy resin by hand layup method to study the mechanical properties of the proposed composite material as a base material for manufacturing of Dental implants. Hardness, impact, tensile strength, compressive strength tests have been conducted on these fabricated composites which were cut according to ASTM standards to study their mechanical properties. Test results exhibited significant improvement in mechanical properties for bilayer structure of the combination of Kenaf, Pine apple, and jute composite material when compared to other combinations of composite materials of this work. This work is very useful in making the composite material which is required for manufacturing of Dental implants.

INTRODUCTION

Dental implants have been used from several years onwards, and since then have developed into highly sophisticated solutions for tooth replacement. It is becoming increasingly important for the materials used in dental implants to exhibit and maintain favorable long term mechanical, biological and more recently, aesthetic Properties. An effective dental biomaterial should osseointegrate, maintain structural integrity, resist corrosion and infection, and not cause systemic toxicity or cytotoxicity. Biomaterials are crucial for modern medical applications, and in the last several decades, these materials have been refined and improved for applications seen in dentistry, orthopedics, drug delivery.

In modern dentistry there is a growing demand for improvements in mechanical, bioactive, and aesthetic properties of tooth replacement implants. Furthermore, the success of dental implants depends on their capability for osseointegration, corrosion resistance, infection prevention, and durability against degradation. Current commercially available biomaterials exhibit a unanimous capability for osseointegration, however, they suffer from limitations in their clinical application.

Plant based fibers such as flax, jute, sisal, hemp, and kenaf have been frequently used in the manufacturing of biocomposites. Natural fibres possess a high strength to weight ratio, non-corrosive nature, high fracture toughness, renewability, and sustainability, which give them unique advantages over other materials. The development of biocomposites by reinforcing natural fibres has attracted attention of scientists and researchers due to environmental benefits and improved mechanical performance. Manufacturing of biocomposites from renewable sources is a challenging task, involving metals, polymers, and ceramics. Biocomposites are already utilized in biomedical applications such as drug/gene delivery, tissue engineering, orthopedics, and cosmetic orthodontics.

Natural fibre reinforced composites have emerged as potential environmentally friendly and cost effective option to synthetic fibre reinforced composites. The availability of natural fibres and ease of manufacture have tempted researchers to try locally available inexpensive fibres and a study of their feasibility for reinforcement purposes and the extent to which they satisfy the required specifications of good reinforced polymer composite for tribological applications. With low cost and high specific mechanical properties, natural fibres present a good, renewable and biodegradable alternative to the most common synthetic reinforcement, i.e., glass fibre . Despite the interest in and environmental appeal of natural fibres, their use has been limited to non bearing applications due to their lower strength and stiffness compared with synthetic fibre reinforced polymer composite. The stiffness and strength shortcomings of bio-composites can be overcome by structural configurations and better arrangement in the sense of placing fibres in specific locations for the highest strength performance. During the last few years, a series of works have been taken up for the replacement of the conventional synthetic fibre by natural fibre composites. For instance, hemp, sisal, jute, cotton, flax and broom are the most commonly used fibres for the reinforcement of polymers like polyolefin, polystyrene, and epoxy resins. In addition, fibres like sisal, jute, coir, oil palm, bamboo, wheat and flax straw, waste silk and banana have proved to be good and effective reinforcement in thermo set and thermoplastic matrices.

Dental implants have become an evidence based treatment for the replacement of missing teeth. Selecting a biomaterial for a dental implant requires additional considerations for biological, mechanical, and aesthetic properties. Modern dental implants need to feature effective osseointegration and maintain long-term stability of their favorable properties to maintain both the implant’s structure and the integrity of surrounding hard and soft tissue (Roehling S et al, 2019; López Píriz R et al, 2019).

Pineapple leaf fibres (PALF) have been reported to be very versatile material with promise for a wide range of biomedical and biotechnology applications such as tissue engineering, drug delivery, wound dressing, and medical implants (Cherian et al. 2010).

Natural fibers are compounds combining cellulose, hemicellulose and lignin; they can be derived from leaves (e.g., sisal), bast (e.g., flax, hemp), seeds (e.g., cotton) or fruit (e.g., coir). The most important advantages of natural fibers relate to environmental issues: they are biodegradable and carbon positive, since they absorb more carbon dioxide than they produce (Bogoeva Gaceva et al. 2007).

A study by (Bilba et al. 2007) used banana leaf fibre as the reinforcement of a composite material, which revealed good improvement in the mechanical properties of the produced composite. The material was also found to degrade under natural environmental conditions.
The rising concern about environmental issues and the need to find a realistic alternative to glass or carbon reinforced composites have led to an increased interest in polymer composites filled with natural organic fibers, derived from renewable and biodegradable sources (Cristiano Fragassa, 2017).

High demand has been placed on natural fibres by the automotive, construction, electrical and electronic industrial markets, making it very competitive. However, the largest consumers of natural fibre composites are the automotive and construction industries (Mohammed L et al, 2015).

The preference for natural fibre emanated from the growing environmental concern, which has led to continuous research on natural fibres and their composite for engineering material applications in place of synthetic fibre (Assarar M et al, 2011)

Productions of composite often involve huge investment in material acquisition. One way of reducing the production cost but still maintaining the properties of the composite is by using natural filler such as rice husks from the waste stream and also a synthesised matrix from the waste stream. Rice husks have been chosen due their availability, low cost, low density, high specific strength and modulus, and recyclability (Rahman et al., 2015).

Natural fibre composites are being utilized increasingly in highperformance, structurally demanding applications, in part because of their material properties and in part because they are a more sustainable choice than other engineering materials, such as mined or petroleum-based materials. Natural fibre composites have excellent specific strength and stiffness properties, meaning that they are very strong and very stiff, but also lightweight (Shah, 2014).

Alavudeen et al. [1] studied the effect of hybridisation on the mechanical properties of banana/kenaf hybrid composites. They reported that the hybridisation of kenaf with banana fibres enhanced the mechanical strength when compared with the individual fibre-based composites. Similarly, another report says that the hybridisation of sisal with oil palm improved the mechanical properties of the composites. Some researchers have investigated the effect s of hybridisation on mechanical properties of banana/sisal composites.

Boopalan et al. (2013) studied the effect s of different weight ratios of jute and banana fibre s on mechanical and moisture absorption properties of jute/banana fibre reinforced epoxy composites. Their study revealed that the tensile, flexural and impact strengths were found to be maximum for 50 :50 weight ratio of jute and banana fibres in the hybrid composites.

Moreover, many natural fibres such as kenaf, hemp, flax, jute, sisal, banana, coir and pineapple leaf fibres , among others , are drawing more considerable attention as a green reinforcement in the formulation of composite materials (Alothman OY, et al, 2019).

In this work, a novel combination of fibres called Kenaf, Pine apple, and jute fibre were taken with treated and untreated forms. The bio fillers are reinforced in epoxy material to prepare composite specimens for Dental Implants applications. Then specimens are cut and their characterization and analysis was carried out.

2. MATERIALS AND METHODS

In this work, composites were prepared using treated and untreated bio fillers in epoxy resin by hand lay-up method to study the metallurgical and mechanical properties of the composites fabricated. Three different natural fibres viz.Kenaf, Pine apple, and jute fibre were used for the preparation of composites. 07 composite specimens were fabricated with different volume fraction percentage of treated bio filler and epoxy polymer as shown in Table 1.

(a) Pine apple Fiber (b) Jute Fiber (c) Kenaf Fiber

Fig. 1. Composite materials

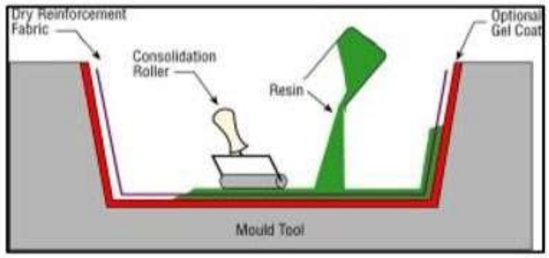


Fig.2 Hand lay up technique

COMPOSITE SAMPLES PREPARATION

In order to develop composite samples, a mold of 15 cm × 15 cm (length × width) and 1.5cm thickness was prepared. A mold release spray was applied at the inner surface of the mold for quick and easy release of the composite. Fibers were uniformly distributed within the boundaries of the mold. In order to ensure uniform fiber distribution, the spreading was done layer by layer so that the averaging

effect will minimize the variation of mass. This method was especially beneficial at low fiber content. No visible voids were found in the prepared samples. A mixture of epoxy and hardener (CHS HARDENER P11) was prepared as per manufacturer (SPOLCHEMIE) guidelines with a ratio of 100:10 and stirred well for uniform mixing. The mixture was dispensed over the fibers in the mold very carefully to ensure uniform distribution of epoxy throughout the samples.

Fig.3 Preparation of natural fiber reinforced composite

a)  b)  c) 

d) e) f)

a)Pine apple(uni directional) composite b) Jute (uni directional) composite c) Kenaf (uni directional) composite d) Pine apple+ Kenaf composite e) Kenaf + Jute composite f) Pine apple+Jute+ Kenaf composite

Fig.4 Preparation of natural fiber reinforced composite

Table 1. Volume fraction of Natural Fibre with Epoxy Polymer

Specimen	Natural Fibre (Vol %)	Epoxy Polymer (Vol %)	Treatment of Natural Fibre	Orientation of the Composite
1	Pineapple (30%)	70%	Treated	Unidirectional
2	Jute (30%)	60%	Treated	Unidirectional
3	Kenaf (30%)	70%	Treated	Unidirectional
4	Hybrid (Kenaf (35%)+Jute (35%))	30%	Treated	Unidirectional
5	Hybrid (Jute(35%)+Pine Apple (35%))	30%	Treated	Unidirectional
6	Hybrid (Kenaf (35%)+Pine Apple (35%))	30%	Treated	Unidirectional
7	Hybrid (Kenaf (30%)+Pine Apple (20%)+ Jute (20%))	30%	Treated	Unidirectional

3. CHARACTERIZATION

Compression Test:

To investigate the compression properties of the samples, universal testing machine Zwick/Roell Z100 by ASTM D 7264 standard was used. Samples were cut as per ASTM standards as $60 \times 60 \times 10$ mm for testing. Ten measurements were taken and the average was reported.

The length, width and depth of each specimen were measured by Vernier Caliper before the test. Each specimen was placed centrally between the two compression plates, such that center of the moving head is vertically above the center of the specimen. Load was applied on the specimen by moving the movable head of the universal testing machine until the specimen breaks. The Ultimate compressive strength was calculated along and across the grains for all samples. The compressive strength was calculated by using equation (1).

Compressive Strength= Maximum load/Cross sectional are of the specimen (1)

Fig.5 Universal testing machine

Impact Test

To investigate the Impact properties of the samples, Charpy Impact tester from Zwick/Roell HIT 50P, Ulm, Germany was used according to ISO 179/1 standard. The energy absorbed by the sample was calculated from the height the arm swings to after hitting the sample. A notched sample was used to determine impact energy and notch sensitivity. Samples were cut as per ASTM standards as $55\times 10 \times 10$mm for testing. Ten measurements were taken and the average was reported.

Fig.6 Impact tester

The width and depth of each specimen were measured by Vernier Caliper before the test. Specimens were placed on the specific slot and the pendulum was allowed to Impact with 30J energy in order to hit and break the specimen. The absorbed energy was recorded, and the Impact strength was calculated with the calculated values of cross-sectional area for all samples. The Impact strength was calculated by using equation (3).

Impact strength= Energy absorbed/ cross sectional area of specimen=E/BD (3)

Where E, is the energy at break, in joules; B, is width of the specimens in millimeters; D, depth or thickness of the specimens in millimeters.

Hardness Test

To investigate the Hardness properties of the samples, Rockwell hardness test was used which consists of indenting the test specimen with a diamond cone or hardened steel ball indenter. The indenter was forced into the test material under a preliminary minor load 60kgf. The indenter used in this test was ¼ ball and the scale was L scale. The permanent increase in depth of penetration, resulting from the application and removal of additional major load was used to calculate the Rockwell hardness. Samples were cut as per ASTM standards E384-16 as 55× 10 × 10mm for testing. Three trails were taken and the average was reported which gives the Rockwell Hardness Number of specimens.

Fig.7 Rockwell hardness Tester

RESULTS AND DISCUSSION

Mechanical Properties

Effect of Fiber Type on Compressive Strength of Composites:

Table2. Compressive Strength of Composite samples

S.No	Specimen	Load (KN)	Area along the grains (mm^2)	Area across the grains (mm^2)	Compressive strength along the grains (N/mm^2)	Compressive strength across the grains (N/mm^2)
1	Kenaf Fiber	36.0	565.73	2766.90	63.63	13.01
2	Jute Fiber	50.5	565.93	2747.45	89.23	18.38
3	Pine Apple fiber	34.3	560.01	2746.36	61.24	12.48
4	Kenf+Jute Hybrid fiber	49.6	562.69	2725.85	88.14	18.19

5	Kenaf+ Pine Apple Hybrid Fiber	54.6	561.94	2722.23	97.16	20.05
6	Jute+ Pine Apple Hbrid Fiber	49.4	561.71	2750.31	87.94	17.94
7	Kenaf+Jute+ Pine Apple Hybrid Fiber	60.0	562.69	2747.85	106.62	22.01

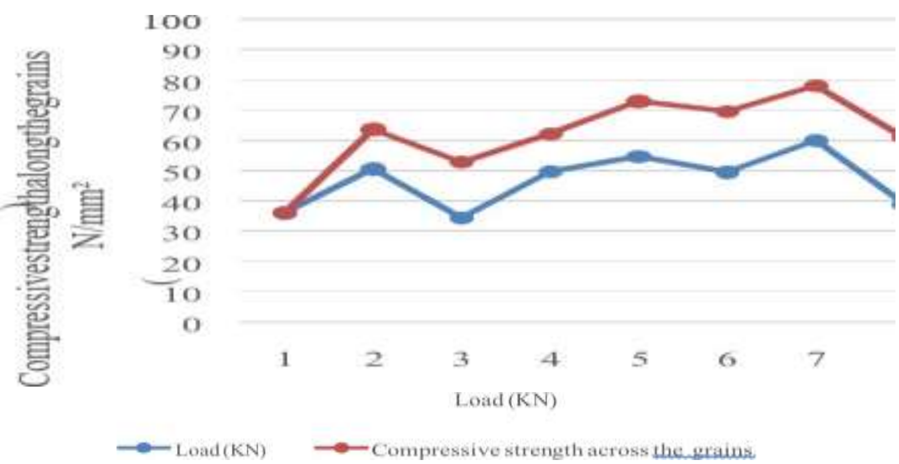


Fig. 8 Compressive strength of composite samples along grains

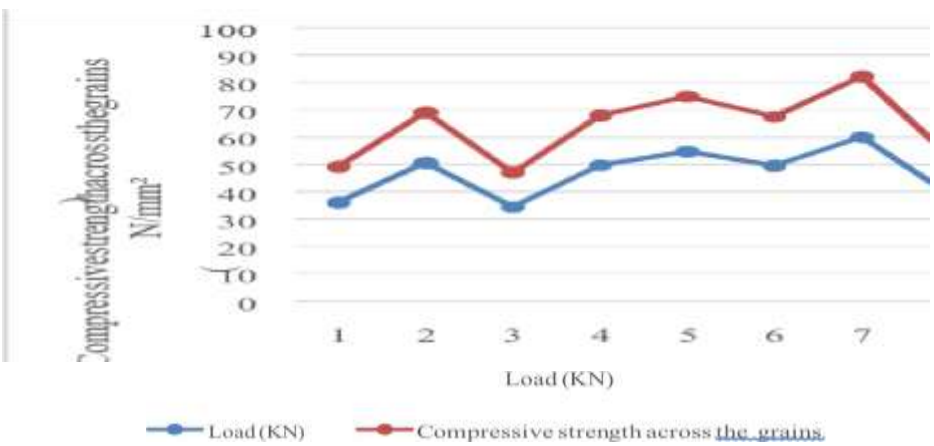


Fig. 9 Compressive strength of composite samples across grains

Compression test has been conducted for seven composite samples. From the results, it has been found that hybrid composite has maximum compressive strength when compared to remaining samples. The maximum compressive strength is obtained in hybrid (kenaf+jute+pineapple) fiber the minimum compressive strength is obtained in pineapple fiber.

Effect of Fiber Type on Impact Strength of Composites:

The ability of the material to resist fracture when load is applied at high speed is known as impact strength. In composites with epoxy resin, the curing process enables the formation of a complex 3D network which increases the mechanical performance substantially. The impact properties of the composites with Kenaf,Pine apple and Jute fibers have been investigated. There is a substantial improvement of impact strength as compared to that of pure green epoxy. The results revealed that the hybrid composite have relatively higher impact strength next to pineapple fiber than the remaining composite samples as shown in Table 3.

Table. 3 Impact Strength of Composite samples:

S.NO	COMPOSITE SPECIMEN	ENERGY ABSORBED BY SPECIMEN (Joule s)	CROSS SECTIONAL AREA (mm^2)	IMPACT STRENGTH(J/mm^2)
1	Jute fiber	4	115.13	0.034
2	Kenaf fiber	3	110.46	0.027
3	Pine apple fiber	10	108.92	0.091
4	Hybrid (Jute+ Pine apple) fiber	6	109.14	0.054
5	Hybrid (Kenaf+Jute) fiber	6	115.13	0.052
6	Hybrid (Pine apple+Kenaf) fiber	4	108.14	0.036
7	Hybrid (Jute+Kenaf+ Pine apple) fiber	8	108.51	0.073

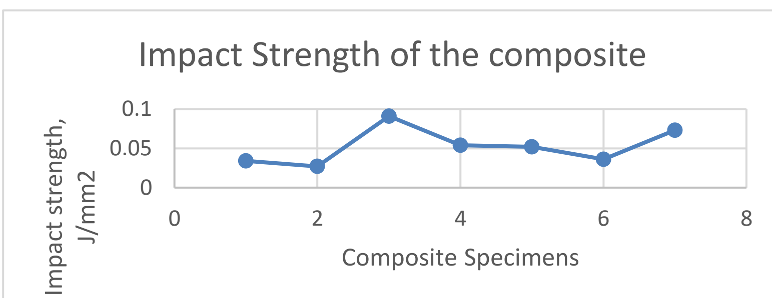


Fig.10 Impact Strength of Composite Samples

Effect of Fiber Content on Impact Strength of Composites:

Charpy impact test has been conducted for the seven composite samples. It has been found that hybrid composite has possess more impact strength next to pineapple fiber compared to remaining composite samples. It should be noted that tenacity of the hybrid fiber is higher than the Kenaf, Pine apple and Jute fibers as shown in Table 3. Further, the hybrid fiber reinforced composites have higher impact strength than the individual fibers composites.

Results revealed that when increasing fiber content, impact strength also increases (Figure 10). It has been observed that hybrid of Jute+Kenaf, Pineapple+Kenaf, Jute+Pine apple composites possess higher impact strength than the individual fiber composites. Than this, the hybrid of Jute+Pine apple+ Kenaf composite possess greater impact strength when compared to other combinations of this work.

It is also observed that, even though the cross sectional area is small for hybrid composite, it was absorbed an energy 08 joules with higher impact strength 0.073 J/mm^2 when compared to remaining composite samples.

Effect of Fiber Type on Hardness of Composites:

The ability of the material to resist fracture when load is applied is known as hardness. In composites with epoxy resin, the curing process enables increases the mechanical performance substantially. The hardness properties of the composites with Kenaf, Pineapple, Jute fibers have been investigated. There is a substantial improvement of hardness as compared to that of pure green epoxy.

Table. 4 Hardness of Composite Samples

S NO	MATERIAL TAKEN	SCALE READING	INDENTOR	LOAD(Kgf)	ROCKWELL HARDNESS			ROCKWELL HARDNESS NUMBER(RHN) avg =
					Trail 1	Trail 2	Trail 3	
1	Kenaf	L	1/4 ball	100	28	26	28	27.3
2	pine apple	L	1/4 ball	100	35	34	37	35.3
3	Jute	L	1/4 ball	100	32	34	31	32.3
4	pine apple +Jute (S. L)	L	1/4 ball	100	37	34	36	35.6
5	Kenaf +Jute (S.L)	L	1/4 ball	100	38	43	44	41.6
6	Kenaf+ pine apple (S.L)	L	1/4 ball	100	34	36	30	33.3
7	Kenaf+ pine apple +Jute (S.L)	L	1/4 ball	100	39	46	40	41.6

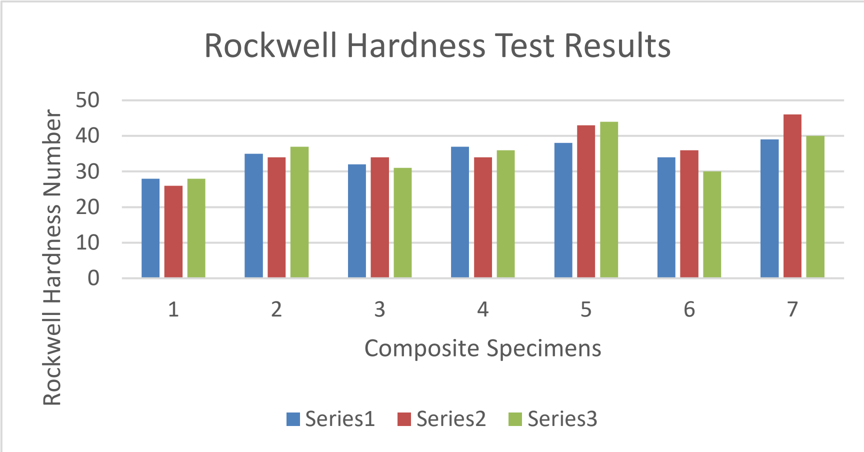


Fig. 11 Hardness of composite samples

Rockwell hardness test has been conducted for seven composite samples. It has been found that Kenaf Jute fiber hybrid reinforced composite and Kenaf, Jute, Pine apple hybrid composite are having same and maximum resistance to indentation when compared to remaining composite samples and the minimum hardness is obtained for Kenaf fiber composite as shown in above Table 4 and Fig. 11.

Metallurgical studies of natural fiber composite materials

In this work metallurgical studies of the prepared natural fiber composite have been conducted using Metallurgical microscopes. The images obtained are analyzed using Micro cam 4.0 software which is a metallurgical image analysis system for finding solutions in metallographic. It is a powerful integration of hardware and software that enables metallurgists to automatically capture images. It is a tool that provides enhancement and measurement visualization analysis and processing of image data.

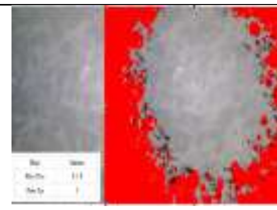
In this work the obtained image of the composite specimens are tested for various parameters like particle measurement, density, nodularity, porosity, grain measurement and flakes. It is found from mechanical characterization results, the Hybrid composite specimens possesses good mechanical properties when compared to other specimens of this study. So that the Hybrid specimens have been considered for this metallurgical study. The results obtained are as follows.

Metallurgical study of Hybrid composite**:**

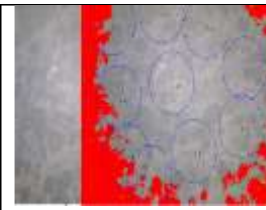
 Before experiment	 Particle measurement	 Density	 Nodularity

Porosity

Grain measurement



Flakes



Grain crack

Fig. 12 Various metallurgical parameters of Hybrid composite

Table. 5. Particle measurement details for Hybrid composite

SL.NO	**1**	**2**	**3**	**4**	**5**
Length	56.613	552.979	46.898	631.599	50.749
Width	35.782	512.979	26.381	396.956	65.785
Area	3506.925	676828.255	792.521	153815.789	3309.418
Asp.Ratio	1.946	1.000	1.940	1.749	1.366
Roundness	45.250	33.087	41.323	43.725	66.262
Shape	0.033	0.035	0.035	0.035	0.017
Box Area	3506.92	676828.255	672.521	153815.789	3309.418
Centriod-X	150	107	255	555	562
Centriod-Y	165	269	397	413	267
Elongation	13.134	35.043	9.01	13.770	6.550
Orientation	159.00	1.007	96.000	156.000	92.000
Circle Diameter	115.03	1914.425	57.403	956.049	135.874
Sphere Volume	109104.52	35803452.53	16840.915	3506836.841	150712.697
Major Axis	55.615	532.99	45.998	621.57	90.749
Minor Axis	13.068	365.31	7.263	33.684	23.469
Thread Length	159.60	3542.35	61.588	1339.151	117.740
Thread Width	17.807	168.36	11.89	117.061	26.966
Fibre Length	164.41	3900.72	64.47	1555.210	152.605
Fibre Width	15.374	131.768	9.39	107.121	23.804
Min.Radius	17.345	629.47	5.98	109.790	23.638
Max.Radius	53.797	981.739	34.36	315.897	37.565

Conclusions

Mechanical properties and Metallurgical studies of Pine apple, Jute and Kenaf in epoxy resin composites with different reinforcement configurations were evaluated. This paper demonstrates that fibre configuration plays an important role in obtaining high mechanical strength. Different mechanical properties in the form of Compression, Hardness, impact, and metallurgical tests were recorded for these composite specimens.

In this work, untreated and treated Pine apple, Jute and Kenaf were taken to study of the composites. It provides better filler and fiber interaction and good interfacial adhesion between filler/ fiber and fewer voids in the composite. Generally, high filler content results in good composite performance, but after a certain limit, the matrix does not adhere well with a saturated amount of filler, and the composite impact strength decreases. So this study encourages the inclusion of treated hybrid fillers in preparing particulate composites. Test results exhibited significant improvement in mechanical properties of hybrid composite material when compared to other combinations of composite materials of this work for manufacturing Dental implants.

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