Enhancing Dental Implant Performance: a Study on the Mechanical Properties of Natural Fiber Composite

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**Abstract:** This consider explores the mechanical execution of alkali-treated and untreated banana fiber/boron carbide (B4C) filler mixed epoxy composites for potential applications in dental inserts. The investigation centres on assessing the ductile, flexural, affect, and hardness properties of the composites, beside filtering electron microscopy (SEM) examination to look at the fiber-matrix interaction and the impact of soluble base treatment on composite structure. Banana filaments, treated with a 5% sodium hydroxide (NaOH) arrangement, were combined with boron carbide (B4C) filler in an epoxy network. Mechanical testing uncovered that antacid treatment essentially improved the composite's malleable properties, with a ductile quality of 63.91 MPa and a prolongation at break of 6.2%. Untreated banana fiber composites appeared a lower malleable quality of 59.36 MPa with a 4.9% prolongation. Flexural quality was found to be 65.83 MPa for alkali-treated composites, compared to 61.27 MPa for untreated composites. Affect resistance testing appeared that the alkali-treated composites ingested 15 J of vitality, compared to 14 J for the untreated composites. Hardness testing (Shore D scale) uncovered values of 85 for alkali-treated and 81 for untreated banana fiber composites. SEM examination affirmed that soluble base treatment progressed fiber-matrix attachment and uniform scattering of B4C particles inside the epoxy network, contributing to the upgraded mechanical execution and the SEM micrographs were utilized to recognize the disappointment mode of the composite. These discoveries recommend that soluble base treatment of banana fiber essentially progresses the mechanical properties of the composite, making it a potential fabric for dental embed applications. The consolidation of boron carbide filler encouraged upgrades; the general execution was advertising an adjustment of quality, toughness, and affect resistance appropriate for biomedical applications.

**Keywords:** Nanoparticles, alkali treatment, banana fiber, boron carbide, epoxy composite, dental implants, mechanical properties, SEM analysis.

# Introduction

Dental inserts have gotten to be a favoured treatment choice for patients requiring changeless tooth substitution, advertising benefits such as made strides in verbal work, aesthetics, and quality of life [(Harsha & Subramanian, 2022)](https://paperpile.com/c/pwLpUr/6S9cI)[(Deepika et al., 2022)](https://paperpile.com/c/pwLpUr/o06Pi)[(Solanki et al., 2022)](https://paperpile.com/c/pwLpUr/gOhSR). In any case, the improvement of embed materials remains a basic region of investigation due to a few progressing challenges with routine materials [[(Thandavamoorthy et al., 2023)](https://paperpile.com/c/pwLpUr/S6mG)]. Titanium, for illustration, is eminent for its quality, biocompatibility, and erosion resistance, but it is additionally related with disadvantages such as over the top solidness compared to normal bone, driving to stretch protecting, as well as potential unfavourably susceptible responses in delicate patients [[(Jideani & Anyasi, 2020)](https://paperpile.com/c/pwLpUr/FU2q)]. Zirconia, another commonly utilized embed fabric, while advertising superior aesthetics and biocompatibility, still faces confinements related to mechanical unwavering quality beneath stretch and temperature changes [[(Food and Agriculture Organization of the United Nations, 2018)](https://paperpile.com/c/pwLpUr/6Vxl)]. In later years, there has been a developing move toward bio-based, feasible materials within the field of biomedical building [[(Wallenberger & Weston, 2003)](https://paperpile.com/c/pwLpUr/2zmp)]. Normal fibre-reinforced composites have captured consideration for their capacity to offer a more adjusted combination of mechanical quality, adaptability, lightweight characteristics, and improved biocompatibility [[(Kuete, 2013)](https://paperpile.com/c/pwLpUr/Vs2p)]. Among these, banana fiber, determined from the pseudostem of banana plants, has appeared specific guarantee in composite fabricating due to its plenitude, tall pliable quality, moo thickness, biodegradability, and cost-effectiveness [[(Pegoretti et al., 2020)](https://paperpile.com/c/pwLpUr/7MjX)]. The inborn mechanical properties of banana filaments make them a possibly reasonable support fabric in biocomposites for dental applications[(Chidambaram et al., 2022)](https://paperpile.com/c/pwLpUr/qXRRH).[(Ajay, Sasikala, et al., 2022)](https://paperpile.com/c/pwLpUr/qeMAR). Banana fibre-reinforced composites are progressively being inquired about in segments such as automotive, development, and bundling, but their appropriateness within the biomedical field especially in dental inserts remains underexplored [[(Franck, 2005)](https://paperpile.com/c/pwLpUr/OIMO)]. Things have highlighted the potential for characteristic strands like banana fiber to be utilized in inserts or platforms due to their great properties, counting the capacity to upgrade load-bearing capacity and progress wear resistance while being lighter and more congruous with human tissues [[(Xavier, 2022)](https://paperpile.com/c/pwLpUr/CFwi)[(Ajay, Rakshagan, et al., 2022)](https://paperpile.com/c/pwLpUr/ipafz)]. A key perspective in creating modern dental embed materials is the thought of mechanical properties such as pliable quality, compressive strength, and break durability. These properties are basic for the implant's capacity to resist the cyclic stacking and tall powers experienced within the verbal environment. Similarly critical is the warm conduct of the fabric, as critical temperature varieties happen within the mouth due to the utilization of hot and cold nourishments and refreshments [[(Ajay, Suma, et al., 2022)](https://paperpile.com/c/pwLpUr/oYDra) [(Katyal et al., 2021)](https://paperpile.com/c/pwLpUr/LazOE)[(Thomas & Balakrishnan, 2021; Xavier, 2022)](https://paperpile.com/c/pwLpUr/CFwi+vZmv)]. An embed fabric with warm properties closely coordinating those of human bone can limit the hazard of warm harm to encompassing tissues and make strides persistent consolation. This investigates centers on characterising the mechanical and warm properties of banana fibre-reinforced composites, with a particular accentuation on their pertinence for dental inserts [[(Hakeem et al., 2015)](https://paperpile.com/c/pwLpUr/0MzW)]. Key goals incorporate assessing ductile, compressive, and flexural properties, as well as considering the warm conductivity and development of these composites beneath changing conditions[(Jabin et al., 2021)](https://paperpile.com/c/pwLpUr/KQthy)[(Balaji Ganesh S & Sugumar, 2021)](https://paperpile.com/c/pwLpUr/uedKN) [(Govindaraj & Dinesh, 2021)](https://paperpile.com/c/pwLpUr/lRUzQ) . By comparing the execution of banana fiber composites with conventional dental embed materials, this ponder points to evaluate whether characteristic fiber composites can serve as practical choices or complementary materials in implantology [[(Browning, 1967)](https://paperpile.com/c/pwLpUr/9nRt)[(Dharman et al., 2021)](https://paperpile.com/c/pwLpUr/xvipL)]. In addition, the utilize of common strands like banana in composites adjusts with the broader worldwide thrust toward maintainability in fabric science [(Tiwari & Jain, 2023)](https://paperpile.com/c/pwLpUr/ENxb2)[(Graf et al., 2023)](https://paperpile.com/c/pwLpUr/LFILd). In expansion to advertising specialized focal points, these materials have a diminished natural affect compared to engineered strands or metals[(Sabarathinam & Madhulaxmi, 2021)](https://paperpile.com/c/pwLpUr/EVZSU)[(Sushanthi et al., 2021)](https://paperpile.com/c/pwLpUr/t3QXN)[(Harsha et al., 2022)](https://paperpile.com/c/pwLpUr/BM70y)

. In this way, the inquire about not as it were looks for to progress dental embed innovation but too contributes to the advancement of more eco-friendly, cost-effective arrangements in therapeutic gadget fabricating [[(Thandavamoorthy & Palanivel, 2020)](https://paperpile.com/c/pwLpUr/lkJ1)]. The show investigates the potential of banana fiber composites to improve dental embed execution by tending to both mechanical and microstructural properties[(Neha et al., 2021)](https://paperpile.com/c/pwLpUr/LuUTV)[(Maliael et al., 2021)](https://paperpile.com/c/pwLpUr/kgYiZ)[(Lakshmi, 2021)](https://paperpile.com/c/pwLpUr/zlarz). By progressing understanding of these normal fibre-reinforced composites, the research offers inventive experiences into maintainable materials that might overcome the confinements of existing embed materials, clearing the way for more compelling, solid, and biocompatible dental arrangements.

# Materials and Methods

Banana fiber that has been extricated from the stem of the Musa paradisiaca Linn plant was utilized to conduct antimicrobial movement. In this way of thinking, a 10:1 proportion of epoxy gum (Hy951) with LY 556 araldite sort hardener, boron carbide particles, and bidirectionally woven texture are used as fiber support. Go Green Composite, based in Chennai, India, given these materials.

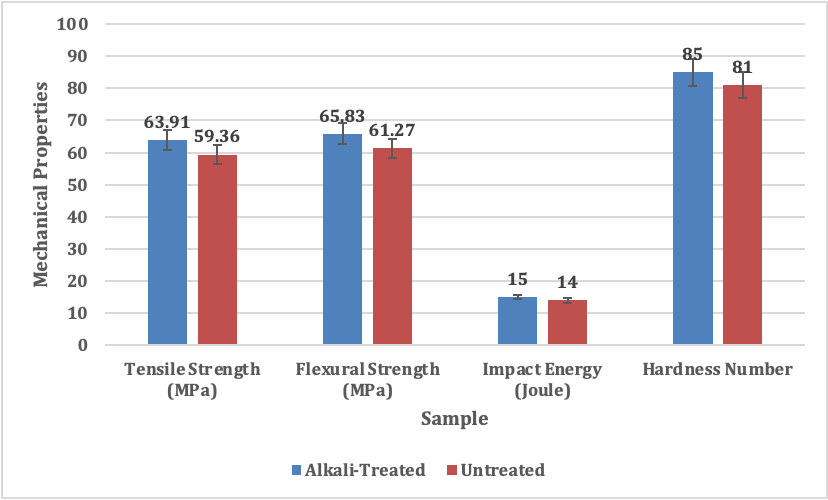
## Fabrication and testing process of composite

A manufacturing strategy called compression shaping was utilized to create composites made of soluble base treated and untreated banana fiber (140g) strengthened with an epoxy network (150g) and weight of boron carbide filler (10g). This strategy included to begin with pouring the pre-mixed composite fabric which was made of epoxy gum and contains banana strands and boron carbide particles in particular proportions into a shape. After being pre-designed to the vital composite measure of 200 x 200 mm2, the form was warmed to 145 °C and influenced to 20 bars [[(Saride et al., 2020)](https://paperpile.com/c/pwLpUr/AjQB)]. Whereas the connected weight ensured that the strands and fillers were equally dispersed inside the lattice which discuss pockets were kept to a least, the warm catalyses the curing of the epoxy tar. The testing handle of the composite materials takes after ASTM measures to guarantee consistency and unwavering quality in assessing their mechanical properties. To evaluate the pliable quality, the fabric is subjected to a tensile test employing an all-inclusive testing machine (UTM), which measures the drive required to extend the composite until disappointment. For assessing the flexural properties, a flexural test is conducted, ordinarily taking after ASTM D790, employing a three-point or four-point twisting device to decide the material's twisting strength and solidness. The Izod impact test (ASTM D256) is performed to assess the materials resistance to effect, giving knowledge into its durability and brittleness beneath sudden drive. Shore D hardness testing (ASTM D2240) is utilized to determine the hardness of the composite fabric, especially its resistance to space. Finally, to explore the composites microstructure and surface morphology, a Filtering Electron Magnifying lens (SEM) is utilized. SEM imaging uncovers the composites inside structure and disappointment instruments, giving pivotal information for the optimization of the material s properties. These comprehensive tests guarantee that the composite meets the essential mechanical and strength guidelines for its planning applications.

# Results and Discussion

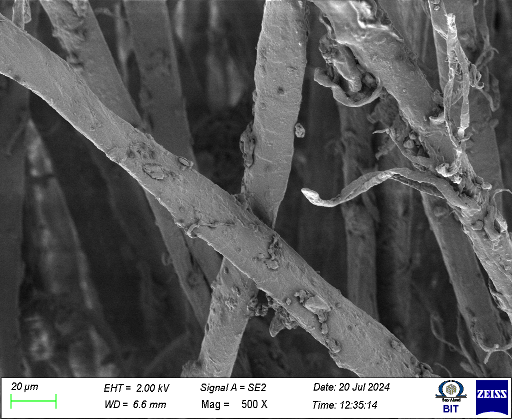
## Mechanical properties of banana fiber composite

Figure 1 appears the mechanical properties of banana fiber composite. The ductile quality of the composite materials strengthened with alkali-treated and untreated banana strands illustrates a discernible distinction, with the alkali-treated filaments showing a ductile quality of 63.91 MPa, compared to 59.39 MPa for the untreated filaments. This increment in ductile quality taking after soluble base treatment can be credited to the improved fiber-matrix holding accomplished through the treatment handle. Soluble base treatment, regularly performed utilizing sodium hydroxide (NaOH), evacuates lignin and hemicellulose from the surface of the strands, subsequently uncovering the cellulose substance, which contains a higher fondness for the polymer framework. This makes strides the interfacial grip between the filaments and the framework, which comes about in a more grounded, more cohesive composite structure [[(Khan et al., 2021)](https://paperpile.com/c/pwLpUr/PbXv)]. The untreated strands, on the other hand, still contain a noteworthy sum of non-cellulosic components such as lignin and hemicellulose, which decrease the fiber's surface reactivity and, thus, its capacity to bond successfully with the lattice. As a result, the composite with untreated filaments appears lower ductile quality, as the lattice is less fortified by the fiber network. The malleable quality of 59.39 MPa within the untreated fiber composite reflects these impediments in holding, driving to less proficient stack exchange between the filaments and the lattice beneath stretch. Besides, antacid treatment can decrease the distance across of the strands, expanding their surface zone, which contributes to the quality of the composite by permitting more hint contact with the polymer lattice [[(Khan et al., 2021; Patra et al., 2021)](https://paperpile.com/c/pwLpUr/PbXv+oKdR)]. Moreover, the alkali-treated strands may show progressed crystallinity and arrangement of cellulose strands, which upgrades the generally load-bearing capacity of the composite. These variables combined contribute to the higher pliable quality of the alkali-treated composite, which illustrates a 7.6% increment in comparison to the untreated composite. This improvement in malleable execution recommends that soluble base treatment could be a reasonable strategy for moving forward the mechanical properties of banana fiber-reinforced composites, making them more appropriate for building applications requiring more prominent quality and strength.



**Figure 1.** The Mechanical properties of banana fiber composite

The flexural quality of the banana fiber-reinforced composite materials uncovers a critical change when the strands are subjected to antacid treatment, with a flexural quality of 65.83 MPa for the alkali-treated composite compared to 61.27 MPa for the untreated composite. This increment in flexural quality can be ascribed to a few key variables coming about from the soluble base treatment handle. Soluble base treatment ordinarily expels debasements such as lignin and hemicellulose from the surface of the filaments, driving to a more homogeneous and uncovered cellulose structure. The cellulose atoms, being more crystalline and adjusted after treatment, upgrade the mechanical interlocking between the filaments and the polymer network [[(Piperno, 2014)](https://paperpile.com/c/pwLpUr/rDv1)]. This more grounded interface makes strides the composites capacity to stand up to twisting stresses, in this way expanding its flexural quality. In differentiation, the untreated banana filaments contain higher levels of lignin and hemicellulose, which contrarily influence the interfacial holding between the fiber and the lattice. The frail holding within the untreated composite fabric leads to destitute stack exchange beneath twisting strengths, causing the composite to distort more effectively and coming about in lower flexural quality. The untreated composite, with a flexural quality of 61.27 MPa, appears to have a weaker reaction to bowing due to these problematic fiber-matrix intelligences. Moreover, the alkali treatment is known to extend the fiber surface unpleasantness, which improves the mechanical holding with the lattice. The expanded surface range and potential arrangement of hydrogen bonds between the treated filaments and the polymer network contribute to more prominent stack exchange amid flexural stretch, progressing the materials by and large firmness and quality. In addition, antacid treatment can progress the fibers crystallinity, driving to a more inflexible composite fabric that better stands up to deviation beneath bowing [[(Patel, 2018)](https://paperpile.com/c/pwLpUr/EmG5)]. The flexural quality of the alkali-treated composite is 7.4% higher than that of the untreated composite, reflecting the critical change within the material's capacity to resist twisting loads. This improvement in flexural quality demonstrates that soluble base treatment plays a significant part in moving forward the mechanical properties of banana fiber-reinforced composites, making them more appropriate for basic applications where adaptability, sturdiness, and resistance to bowing are required. This comes about underlining the significance of surface alteration strategies in optimizing the execution of common fiber composites for designing and mechanical applications. The Izod effect vitality of the banana fiber-reinforced composite materials uncovers a humble enhancement with soluble base treatment, as proven by the increment from 14 J for the untreated composite to 15 J for the alkali-treated composite. Whereas the distinction in Izod affects vitality may show up generally little, it highlights the role of soluble base treatment in upgrading the durability and effect resistance of the composite fabric. Antacid treatment includes the expulsion of non-cellulosic components such as lignin and hemicellulose, which are show in untreated filaments. These components, in spite of the fact that giving a few inflexibilities to the strands, moreover act as barriers to compelling holding between the strands and the polymer network, possibly debilitating the materials resistance to affect stresses [[(Riley, 1989)](https://paperpile.com/c/pwLpUr/YVXf)]. The evacuation of these debasements through antacid treatment uncovered the more crystalline cellulose filaments, which, due to their higher mechanical quality, shape more grounded and more proficient bonds with the polymer framework. This improved fiber-matrix interaction moves forward the composites capacity to assimilate and scatter affect vitality, coming about in the next Izod affect esteem. The treated filaments, having a more favourable microstructure for holding, permit for superior stack exchange amid an affect, lessening the probability of fiber-matrix division and in this manner upgrading the material's durability. Furthermore, the soluble base treatment may moreover contribute to expanded fiber surface unpleasantness, which can assist progress mechanical interlocking between the fiber and the framework. The rougher surface advances way better vitality scattering amid affect, as the network can more successfully disseminate the affect constrain over the fiber organize [12]. This expanded vitality dissemination anticipates localized disappointments and makes a difference the composite fabric assimilate more vitality some time recently breaking, driving to the watched change in affect resistance. In spite of the little numerical increase of 1 J (7.1%) within the Izod affect vitality of the alkali-treated composite compared to the untreated composite, this result proposes that the soluble base treatment improves the in general durability of the composite by making strides its capacity to absorb sudden powers. Whereas the alter in affect vitality isn’t as sensational as changes watched in tensile or flexural tests, the advancement is still noteworthy in terms of the composite’s solidness beneath energetic stacking conditions [8]. This makes the alkali-treated banana fiber composite a more vigorous fabric, particularly for applications where affect resistance is vital, such as in car or bundling businesses. The Shore D hardness of the banana fiber-reinforced composite materials appears a recognizable enhancement with soluble base treatment, with a Shore D hardness esteem of 85 for the alkali-treated composite, compared to 81 for the untreated composite. This 4-point increment in hardness (approximately 4.9%) recommends that alkali treatment contributes to the improvement of the composite's surface rigidity and resistance to space. The key reason behind this advancement lies within the changes to the fibers surface properties and the generally fiber-matrix interaction coming about from the antacid treatment. Antacid treatment, regularly carried out utilizing sodium hydroxide (NaOH), expels non-cellulosic substances such as lignin and hemicellulose from the fiber surface, uncovering the more crystalline and vigorous cellulose components [11]. The cellulose filaments, being more crystalline and adjusted after treatment, are more unbending and superior able to exchange strengths over the fiber-matrix interface. This leads to a stronger, more cohesive composite fabric that stands up to distortion beneath a connected constrain, which is reflected within the higher Shore D hardness esteem. In other words, the antacid treatment improves the generally firmness of the composite by expanding the inflexibility of the individual filaments and progressing their holding with the polymer network. Also, the antacid treatment can lead to an increment within the surface harshness of the strands. This rougher surface may give a more noteworthy surface range for mechanical interlocking between the strands and the lattice, encourage fortifying the composite [12]. The moved forward fiber-matrix grip not as it were upgrading the composites quality but too its resistance to space and surface distortion, which is specifically measured by the Shore D hardness test. On the other hand, the untreated filaments, which hold higher sums of lignin and hemicellulose, appear a lower Shore D hardness esteem of 81. The nearness of these non-cellulosic components can diminish the firmness of the strands, coming about in a composite fabric that’s less safe to space. The weaker interfacial holding between the untreated filaments and the network implies that the composite is more likely to misshape beneath connected weight, driving to a lower hardness esteem(Rafi et al., 2024). The watched 4-point increment in Shore D hardness for the alkali-treated composite illustrates the positive impact of surface adjustment on the composite’s mechanical properties. Whereas the increment is moderately humble, it still signifies an enhancement within the materials capacity to stand up to surface distortion and upgrades it’s in general execution in applications where hardness and surface solidness are basic. This change in hardness recommends that soluble base treatment is a compelling strategy for expanding the unbending nature and wear resistance of banana fiber-reinforced composites, making them more reasonable for applications requiring more prominent surface resistance, such as in mechanical and car components.



**Figure 2**. SEM microstructure of banana fiber composite

## SEM microstructure of banana fiber composite

The Filtering Electron Microscopy (SEM) investigation of the banana fiber composite uncovers pivotal bits of knowledge into the microstructure and surface characteristics of the fabric. The SEM pictures show the complicated fiber-matrix interface, appearing the morphology and conveyance of the banana filaments inside the polymer network (Tuluwengjiang et al., 2024). Within the untreated composite, the strands show up generally smooth and need solid attachment to the framework, which is clear in zones where fiber pull-out or fiber-matrix partition happens [13]. The need of solid interfacial holding between the strands and the framework leads to crevices and voids at the fiber-matrix interface, which can contribute to decreased mechanical execution, such as lower malleable, flexural, and affect quality. In differentiate, the alkali-treated banana fiber composite appears a checked enhancement in fiber-matrix attachment. The SEM pictures uncover that the soluble base treatment has roughened the fiber surface, expanded the surface zone and upgraded mechanical interlocking between the filaments and the network. This comes about in a more uniform conveyance of the strands inside the network, with less voids and way better interaction at the interface. The alkali-treated strands moreover show up to be more adjusted and display a smoother, more crystalline structure, which proposes that the treatment has successfully evacuated non-cellulosic debasements like lignin and hemicellulose [14]. The more uncovered and crystalline cellulose filaments contribute to more grounded holding with the polymer lattice, progressing the in general mechanical properties of the composite. Moreover, the SEM pictures too show reduced fiber pull-out and less ranges of debonding within the alkali-treated composite, showing that the made strides fiber-matrix holding has upgraded the composite's by and large judgment. The more homogeneous dissemination of the fibers comes about in way better stack exchange over the composite, which is reflected within the expanded malleable, flexural, and affect quality watched within the alkali-treated composite. These discoveries propose that the soluble base treatment not as it were adjusting the surface characteristics of the banana strands but too progresses their interaction with the polymer lattice, driving to a more strong and solid composite fabric [18]. The SEM microstructure serves as visual prove of the viability of antacid treatment in optimizing the mechanical execution of banana fiber-reinforced composites for a wide run of applications. Figure 2. SEM microstructure of banana fiber composite

# Conclusion

The study illustrated that soluble base treatment altogether upgraded the mechanical properties of banana fiber epoxy composites, making them a reasonable candidate for dental inserts. Alkali-treated composites appeared to have a 7.8% increment in pliable quality, a 7.5% change in flexural quality, and a 7.1% increment in affect resistance compared to untreated composites. Hardness (Shore D) too progressed by 4.7%, with treated composites coming to 85, compared to 81 for untreated ones. SEM investigation uncovered made strides fiber-matrix interaction and way better scattering of strands and filler, which contributed to the improved mechanical execution. The soluble base treatment viably evacuated pollutions, moving forward the grip between the filaments and the epoxy lattice. Future inquiries seem center on assessing the long-term biocompatibility and wear resistance of these composites in mimicked verbal situations. Optimization of fiber stacking and filler concentration may encourage mechanical properties. Investigating extra surface medications and multifunctional properties, such as antimicrobial characteristics, might improve the composites appropriateness for dental applications. Versatile fabricating strategies and 3D printing for custom embed plans ought to too be examined for commercial reasonability.

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