A Study Of The Effect Of Tio$_2$ And Al$_2$O$_3$ On Tribological, Mechanical Properties And Microstructure Of PMMA And LDPE Polymer Composites Can Used As Tibial Insert In Total Knee Replacement Implant

K R Dinesh, Gururaj Hatti

Abstract: In total knee replacement the whole knee joint is substituted by the artificial materials like ceramic, metal, or polymeric which will act has load bearing joint. Knee spacer is the component of TKR which is used to look-alike the articular cartilage. In this paper, we report the result of titanium oxides and alumina on tribological, mechanical properties and microstructure of polymer composites fabricated by injection moulding technique. Due to prominent applicant of polymer composites low cost, high strength and ease of fabrication, now a days they are used to prepare implant materials. Polymers when used in their real form they pose truncated mechanical and tribological properties. Due to this reason polymers are reinforced with the other available materials (ceramics) to increase the mechanical and tribological properties. In this research we used TiO2 and Al2O3 ceramics to reinforce the PMMA and LDPE polymers matrix. Specimens are prepared according to ASTM standard with changing the percentage of alumina in both matrixs. Bending, Impact, hardness, wear tests are carried along with biocompatibility test.

Key-words: PMMA, LDPE, TiO2, Al2O3, Injection moulding, Extruder Machine, Pin-on-disc

1 Introduction:

Hybrid Polymer composites are making sound in recent years in the field of implant materials due to significant improvement in tribological and mechanical properties. With addition of the different compounds in powder like glass fibers, carbon nanotubes and carbon black which are acting as a reinforcement to polymer matrix make it more efficient materials in terms of mechanical, tribological and thermal properties, when compared to their original counterparts. Apart from improvement in different properties they are also cost effective and ease to fabricate. This may help to produce a new kind of hybrid polymer matrix composites which can be used has an implant material. The addition of different compounds which are reinforcements to matrix which enhance the mechanical and tribological properties due to interfacial bonding between compound and matrix and also biocompatibility which is the main requirement of implant material [1]-[5]. Polyethylene is easily available one kind polymer and very cost effective which can be processed under temperature of 150-200 0C. Polyethylene has cross linked and are of linear low-density polyethylene, low density polyethylene, high density polyethylene. Cross linking is very much helpful which have branched structure. Cross linked Polyethylene like low density polyethylene, high density polyethylene, due to cross linking they possess the dense grid of high MW, which improves bearing strength, crack resistance, and density to any appreciable extent. A thermoplastic, Polymethylmethacrylate (PMMA) is a conceivable lightweight, break safe substitute for glass PMMA in its unmodified structure can be weak with especially poor effect durability and has a lower hardness. In any case, when changed, with addition of reinforcements both of these properties can be altogether improved [6]-[8]. To improve the properties of the considered polymers in this investigation viz., LDPE and PMMA, titanium oxides (TiO2) and alumina (Al2O3) are used has a reinforcement. This as been considered as per the literature survey. Alumina is stable up to a 20000C and it is a stiff material with a great hardness rate. Titanium and its compounds are very much used in the medical field applications because of their biocompatibility, by literature survey it is seen that by using Titanium and its compounds no chemical reaction is observed when used as hard tissue substitute as well as other biomedical applications. In the present investigation two composites are going to be prepared using LDPE and PMMA as matrix and titanium oxides (TiO2) and alumina (Al2O3) has a reinforcement in both composites. Composites prepared as per ASTM standard using injection moulding technique. Prepared specimens are tested for its various mechanical properties, tribological property [9]-[10].

2 Materials and Methods:

Commercially available polyethylene is of three grades. In which ultra-high molecular weight polyethylene is having very poor ductility and rupture durability when compared to other polyethylene grades. Due to this low-density polyethylene have been considered because of its high cross-linked structure which make it denser so it is chosen for the experimentation as one of the polymer matrix material. Nowadays, acrylic bone cements are widely used in dentistry, in orthopedics for cementation of joint prostheses, in neurosurgery for skull reconstructive surgery, and in spinal surgery for vertebroplast, providing a relevant contribution to the long-term success of these surgical techniques. Due to this it is considered as another polymer matrix material. The above-mentioned polymer matrix materials have low mechanical and tribological properties. Hence to enhance the properties, in the present work titanium oxides (TiO2) and alumina (Al2O3) are used has a reinforcement in both polymer matrix material. Titanium Dioxide powder of 325 mesh size and alumina of 275 mesh size used in this study has reinforcement of both considered polymer matrix materials. Based on the literature review the weight percentage of polymer matrix material, Alumina and Titanium Dioxide were decided. Table 1 shows the fraction of matrix and strengthening material used for combination of polymer-ceramic composites.

TABLE 1: COMPOSITIONS OF COMPOSITE MATERIAL

Sr. No.	LDPE (%)	TiO2 (%)	Al2O3 (%)
1	87	5	8
2	79	5	16

Sr. No.	PMMA (%)	TiO2 (%)	Al2O3 (%)
1	87	5	8
2	79	5	16

Testing samples were fabricated according to ASTM standards (figure 1). ASTM D790 standard for flexural test and ASTM D256 for impact test specimens.

(a)

(b)

Figure 1 (a) PMMA (b) LDPE composites test samples

Extruder and Injection moulding were used for specimen's preparation. For composition (PMMA, TiO2 and Al2O3), initially PMMA which is in granule form is weighted and according measured amount of titanium oxides (TiO2) and alumina (Al2O3) which are in powder form are mixed and transported to hopper of the extruder. The screws of the extruder transfer the mixture through the series of heating zone of the extruder were mixture gradually melted. The molten polymer composition is forced through die and it become hard due to cooling when it come through any cooing medium (water or Air). This obtained composition is made into small pieces using mill cutter and these pieces of compositions are fed into the hopper of the injection moulding were pieces are slowly moved forward by a screw-type plunger, the pieces are forced into a heated chamber, where it is melted. As the plunger advances, the melted pieces are forced through a nozzle into the mould where it takes the contrary shape of it. Similar procedure should be followed to make (LDPE, TiO2 and Al2O3) composition.

Flexural and Impact test were carried in the SJCE PST department laboratory, Mysuru, Karnataka. Biocompatibility test were performed at our institute. Microstructure (SEM images) were taken from Sophisticated Analytical Instrument Facility, Dharwad, Karnatak University, Dharwad.

3 Results:

This study describes the mechanical, wear performance of PMMA/LDPE + TiO2+Al2O3 composites. Samples got ready as per ASTM using extruder and injection moulding. Table 2: indicate the consider amount matrix and reinforcements.

TABLE 2: DESIGNATIONS AND CONSIDER AMOUNT MATRIX AND REINFORCEMENTS

Composition	Designation
PMMA+5%TiO2+8%Al2O3	PMMA-I
PMMA+5%TiO2+16%Al2O3	PMMA-II
LDPE+5%TiO2+8%Al2O3	LDPE-I
LDPE+5%TiO2+16% Al2O3	LDPE-II

3.1 Flexural strength: Flexural strength was calculated and as shown in figure 2. The test conducted according to the ASTM D390 testing standard.

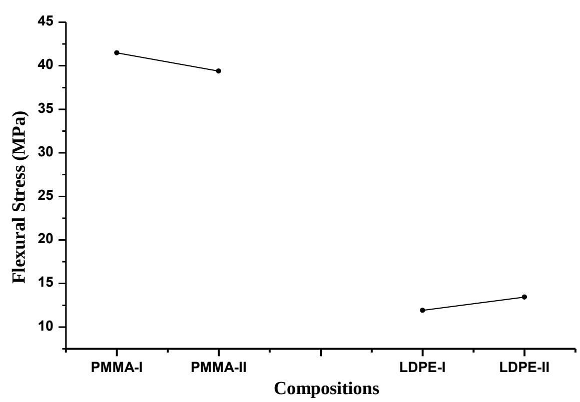


Figure 2: Flexural strength of PMMA/LDPE + TiO2+Al2O3 composites.

Flexural strength calculated and are showed in figure 2. Alumina addition leads to both increased and decreased flexural strength depending upon the amount added. It can be seen from the graphs that flexural strength decreases with increases in the amount of Al2O3 in PMMA matrix this is due to higher concentrations can be attributed to decrease in cross section of load bearing polymer matrix; stress concentration because of too many filler particles; changes in the modulus of elasticity of the resin and mode of crack propagation through the specimen due to an increased amount of fillers incomplete wetting of the fillers by the resin; and the fact that aluminium oxide acts as an interfering factor in the integrity of the polymer matrix. For the LDPE-Al2O3 based composites its behaviour is seen from figure 2 that flexural quality increments with the expansion in the level of alumina. This might be because of the nearness of hard and hardened alumina particles in the composite material. Alumina particles oppose the misshaping of the composite material, in this manner the flexural quality increments.

3.2 Impact strength: Impact strength is the capability of the material to withstand a suddenly applied load and it is calculated by noting down the energy observed, for approximating the impact strength. Figure 3 shows the impact strength of the consider compositions.

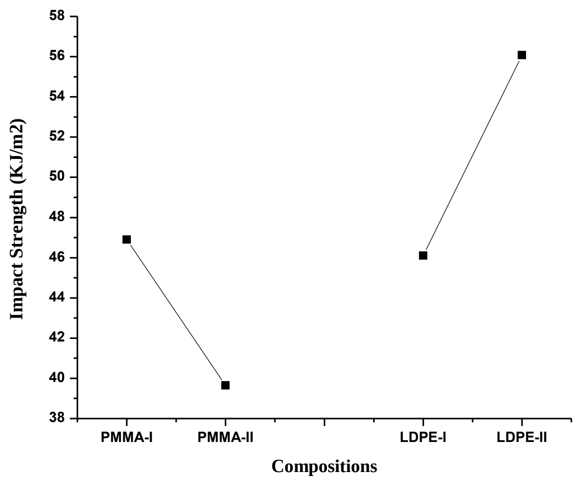


Figure 3: Impact strength of PMMA/LDPE + TiO2+Al2O3 composites

Figure 3 shows the discrepancy of impact strength with the variation in fraction of alumina. Alumina had marginal influence on the fracture energy under impact load. As the presence of alumina increases in the PMMA matrix increases this decreases the ductility of the composite due to this observing the energy by the composite before failure decreases, ultimately there is a decrease in the impact strength. In case of LDPE composite as alumina is stiff and harder material, it raises flexural quality and reduces the flexibility of the material. As flexibility reduces the strength seen by the material before disappointment diminishes, thus the effect quality reductions.

3.3 Wear: Test conducted with following parameters. Minimum load 2Kg and Maximum 4kg, sliding speed of 400 rpm and the entire test were carried out for 15 mins duration. Track diameter 80mm.

Calculation
Wear rate =volume loss/sliding distance
Force friction (ff) =enter (n)
Coefficient friction (cof) =Frictional force/load
At 1.67 m/s
N=400rpm
Time=15min

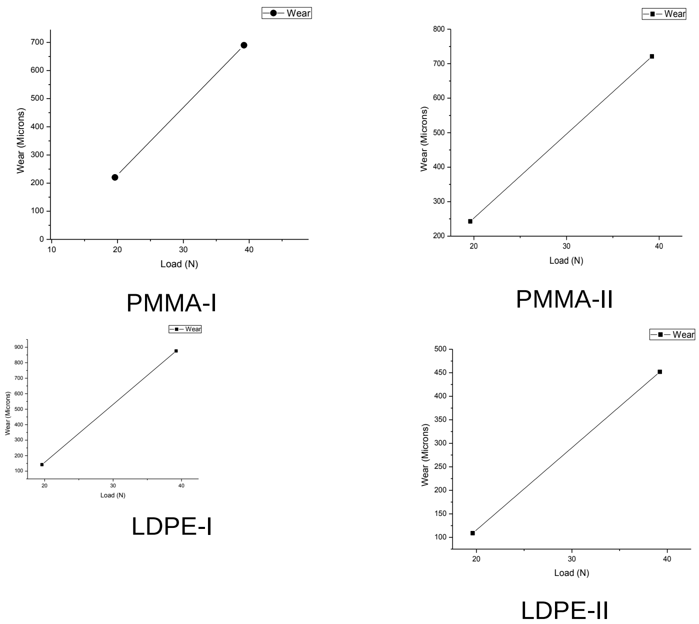
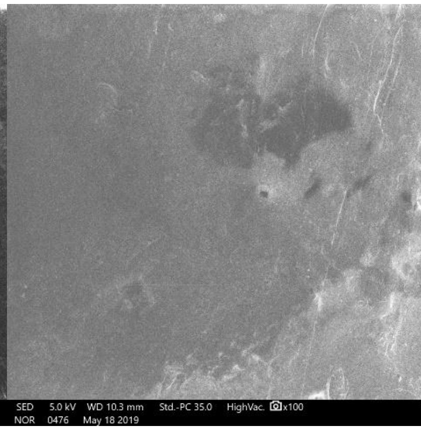


Figure 4: Wear (Microns) of compositions

The wear on the on both consider composites are shown in figure 4. In case of PMMA- Al2O3 it is discovered that the expansion of firm incorporations, diminished the grinding coefficient. Higher rough coefficient and more wear rate were estimated at higher connected burdens. The diminished worn mass with expanding the alumina fixation can be ascribed to the heap bearing limit of alumina particles and the higher quality and hardness of the ragged surface. Then again, the lower part coefficient may be because of the hindering impact of hard incorporations on the bond and delamination of the milder framework. In case of LDPE - Al2O3 based composites Wear of the composite material is less because of the nearness of alumina particles which builds the wear resistance of the composite material. Because of harder and stiffer nature of alumina particles prompts increment the insurance from strip off or scratch of the composite material. The base of coefficient of grinding may be a direct result of nature of alumina particles which aides in moving contact rather than sliding discordant.

3.4 Microstructure: Samples were observed under the scanning electron microscope. Figure 5 & 6 shows the images of composites under 100X,200X and 500X magnification.


Magnification x100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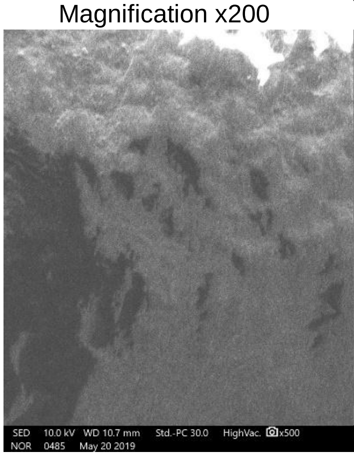
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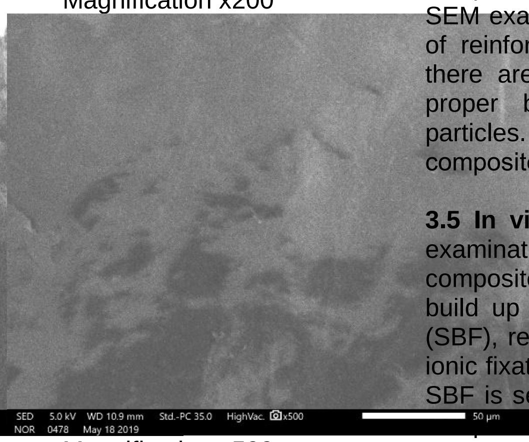
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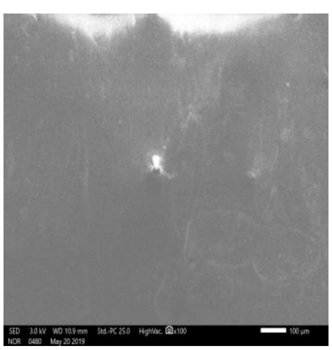
Figure 5: SEM images of PMMA-I & PMMA-II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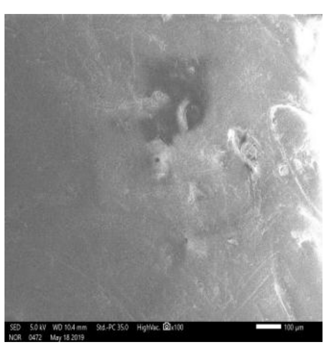
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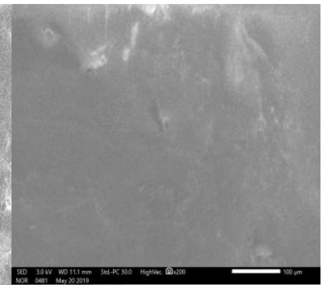
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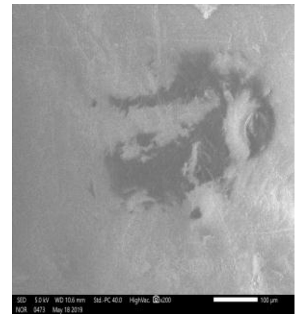
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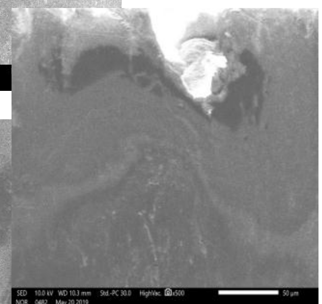
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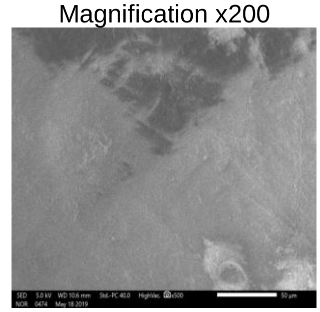
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Figure 6: SEM images of LDPE-I & LDPE-II

SEM images of the PMMA- Al2O3 based composite at different magnifications are shown in Figures. SEM examination of the samples revealed that no cavities or cracks were detectable. In case of LDPE- Al2O3 based composite at different magnifications are shown in Figures. SEM examination that there is a homogeneous distribution of reinforcing particles in the matrix of the polymer and there are no casting defects observed. Also, there is a proper bonding between the matrix and reinforcing particles. This enhances the mechanical properties of the composite's materials.

3.5 In vitro Biocompatibility test. In vitro Bio measure examination is done to assess the capacity of created composite example to frame bond with living tissue and to build up a layer when drenched in recreated body liquid (SBF), reenacted body liquid is a watery arrangement with ionic fixation arrangement like that of human blood plasma. SBF is set up as announced by kokubo et al. Densities of composite examples were determined utilizing Archimedes rule when dunking the composite examples in SBF. By test it demonstrates that thickness of composite examples increments subsequent to plunging in SBF arrangement. Concoction response happens between the outside of composite examples and particles shows in SBF arrangement with time. This outcomes in development of crystalline layer, and results in elevation of thickness of composite specimens. Figure 7 shows the SBF preparation and Placing specimens in the prepared SBF.

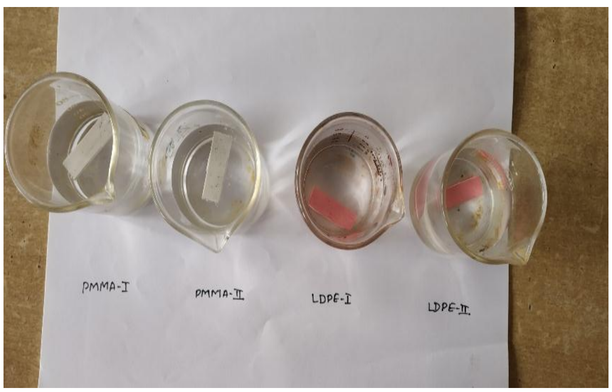

Figure 7: SBF preparation and Placing specimens in the prepared SBF.

4 Conclusion

In this present work examination had made to create a polymer framework composites for biomaterial application. Following ends can be drawn dependent on the aftereffects of present work.

1. Flexural quality declines with increments in the measure of Al2O3 in PMMA grid this is because of higher fixations can be ascribed to diminish in cross segment of burden bearing polymer network; stress focus on account of an excessive number of filler particles.
2. LDPE-Al2O3 based composite it tends to be seen from the diagram that flexural quality increments with the expansion in the level of alumina.
3. Impact quality declines with increment in the level of alumina in both PMMA and LDPE based composite material.
4. Hardness increments with increment in the level of alumina in both PMMA and LDPE based composite material.
5. Coefficient of interaction is less in both PMMA and LDPE based composite material with increment in the level of alumina.
6. SEM pictures demonstrate a homogeneous conveyance of strengthening molecule and appropriate holding among framework and fortification.

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