Chapter 5: SUMMARY AND FUTURE PROSPECTS

5.1 Summary

In recent studies, many nanofillers are being used along with polymer in order to enhance its properties for bone tissue engineering applications. The polymer PCL is one of the most explored polymers for bone tissue engineering as it biocompatible, biodegradable, and strong to certain extent. It has certain drawbacks like low mechanical strength and low osteogenicity. The idea of using a ceramic was it being inorganic and its potential to mimic the inorganic (mineral) part of bone. The nanofillers (nSiO₂, NC & MF-nHAp) used in this study, in our opinion help to overcome the drawbacks and acts as a better scaffold for bone tissue engineering. The nanofibrous morphology helps to mimic the ECM of bone, further aiding the scaffold in promoting bone regeneration.

Most importantly, the novelty of the study was to explore the MR functionality of the MF-nHAp particles in the scaffold. HAp being a constituent of human bone is the best filler to mimic the bone ECM. The incorporation of these MF-nHAp particles not only imparted MR functionality to the scaffold, but also showed changes in the MR contrast at different stages of bone regeneration. Hence it could be beneficial for implant related studies for bone tissue engineering.

In this dissertation we performed a study on three different nanoceramics incorporated in nanofibrous PCL scaffolds mechanically, chemically and biologically. From these studies, we can infer the following:

- All the ceramic nanofillers incorporated in the PCL polymer, proved to be biocompatible and supported proliferation. Also, these nanoceramics when incorporated in PCL nanofibrous scaffolds enhanced the mechanical strength of PCL nanofibrous scaffold.

- PCL/nSiO₂ scaffold showed highest increase in protein adsorption compared to all scaffolds studied as nSiO₂ was the smallest particle of all the nanofillers. It also was the most hydrophobic scaffold. The PCL/nSiO₂ scaffold was
biocompatible but free nSiO₂ nanoparticles were found to be toxic to hMSCs. Hence use of the PCL-nSiO₂ scaffolds for bone tissue engineering would need to take into account any potential long-term impact of these particles if they leached out from the engineered bone.

- The PCL/NC scaffold showed better mechanical strength and differentiation compared to PCL scaffolds. NC was used as a replacement for nSiO₂, as free nSiO₂ was toxic. The solvent dichloromethane used for intercalation is toxic, to avoid its traces, it would be beneficial if the intercalation could be done with a bioinert/biocompatible solvent.

- The MF-nHAp containing nanofibrous scaffolds promoted proliferation of hMSCs compared to all nanofibrous scaffolds studied. The PCL/MF-nHAp scaffold showed significantly higher protein adsorption compared to PCL nanofibrous scaffold and aided early differentiation of hMSCs to osteoblasts compared to other nanofibrous scaffolds. The mechanical strength of the PCL/MF-nHAp was found to be the highest of all the composite scaffolds.

- Most importantly, the PCL/MF-nHAp scaffold had the property of MR-functionality, and preliminary results suggest that these scaffolds could be used for early monitoring of the developing bone tissue construct along with hMSCs. Hence can help monitoring in real time the changes during the process of bone regeneration after implantation. Considering all the properties of a scaffold needed for bone tissue engineering, PCL/MF-nHAp appears to be most suited for bone tissue engineering.

### 5.2 Future Prospects

- This study gives a broader understanding of which material works better for the purpose of bone tissue engineering. Considering the PCL/MF-nHAp was the best of the scaffolds studied, we would suggest this material for future applications in bone tissue engineering.

- PCL/MF-nHAp nanofibers which showed the improved mechanical properties and biological properties can be used for developing 3D nanofibrous constructs
for future applications in bone tissue engineering which need mechanical strength and structural dimensions of natural ECM.

- The PCL/MF-nHAp scaffold after conditioning in a bioreactor using appropriate growth factors and stimuli along with hMSCs can be developed into a tissue engineered construct ready for implantation.

- This PCL/MF-nHAp scaffold can be taken further to in vivo studies to check the response due to the implant in the animal as well as the leaching of the MF-nHAp particles from the scaffold and fate of the nanoparticle.

- Considering the positive results from the preliminary MRI studies obtained, the animal MRI can be performed to study the post-implantation changes in the bone tissue (PCL/MF-nHAp along with hMSCs) and confirm if bone tissue regeneration can be monitored in vivo using this MR-functional scaffold.

- This scaffold in combination with an appropriate hydrogel could be used to treat osteochondral defects.