# Pengaruh Waktu Agitasi Hidroksiapatit pada Modifikasi Permukaan Scaffold Berpori Berbahan Dasar Polylactic Acid (PLA) terhadap Sifat Shape Memory Effect dan Bioaktivitas = The Influence of Hydroxyapatit Agitation Time on Surface Modification of Porous Scaffold Based on Polylactic Acid (PLA) towards Shape Memory Effect and Bioactivity

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Abstrak

Inovasi dalam bidang rekayasa jaringan dan manufaktur aditif mendorong pengembangan scaffold tulang cerdas yang dapat disesuaikan secara kustomisasi. Scaffold cerdas ini meniru sifat mekanik dan biologis tulang asli, dan memiliki kemampuan self-fitting. Penelitian ini bertujuan untuk menguji pengaruh penambahan senyawa bioaktif hidroksiapatit (HAp) pada scaffold berbahan PLA yang dibuat menggunakan metode pencetakan 3D FDM. Scaffold PLA kemudian dilapisi dengan lapisan HAp melalui proses perlakuan alkali selama 1 jam, diikuti dengan coating dispersi 1% w/v HAp. Penambahan HAp bertujuan untuk meningkatkan biokompatibilitas dan bioaktivitas scaffold. Variabel yang diamati dalam penelitian ini adalah waktu agitasi coating dispersi HAp, yaitu 0,5, 1, dan 2 jam. Pengaruh waktu agitasi terhadap bioaktivitas dan sifat mekanik scaffold diamati melalui pengujian imersi dalam larutan simulasi cairan tubuh (r-SBF), pengujian swelling, observasi visual menggunakan mikroskop optik, SEM & EDS, dan pengujian kompresi dinamis. Hasil pengujian imersi menunjukkan bahwa scaffold PLA/HAp memiliki bioaktivitas enam kali lipat dibandingkan dengan scaffold PLA dengan variabel 1% w/v HAp-1 jam sebagai kondisi optimal. Deposisi mineral apatit terjadi selama tujuh minggu imersi dalam r-SBF, sedangkan perubahan warna PLA terjadi pada minggu ketiga hingga keempat. Hasil SEM & EDS pada scaffold imersi r-SBF selama 7 minggu menunjukkan ukuran deposisi apatit lebih besar pada sampel PLA/HAp, munculnya porositas pada permukaan scaffold, dan retakan permukaan.  Hasil pengujian swelling menunjukkan peningkatan rasio swelling seiring peningkatan waktu agitasi, yang menunjukkan peningkatan sifat hidrofilik scaffold. Namun, penambahan waktu agitasi juga berhubungan dengan penurunan kemampuan self-fitting scaffold. Scaffold PLA dapat mengalami enam siklus kompresi dan pemulihan sebelum mengalami kegagalan, sebesar 97-99%. Sementara itu, scaffold PLA/HAp mengalami kegagalan setelah dua siklus kompresi dan pemulihan, dengan pemulihan mencapai 90-91% akibat intrusi HAp pada penampang strut. Secara keseluruhan, penambahan HAp pada scaffold berbasis PLA meningkatkan biokompatibilitas dan bioaktivitas. Kondisi optimalnya adalah 1% w/v HAp-1 jam, memberikan solusi yang menjanjikan untuk aplikasi regenerasi medis dan rekayasa jaringan.

.....Innovation in the field of tissue engineering and additive manufacturing is driving the development of customizable smart bone scaffolds. These smart scaffolds mimic the mechanical and biological properties of natural bone and possess self-fitting capabilities. This research aims to investigate the influence of adding bioactive compound hydroxyapatit (HAp) to PLA-based scaffolds produced using the FDM 3D printing method. The PLA scaffold was subsequently coated with an HAp layer through an alkaline treatment process for 1 hour, followed by a 1% w/v HAp dispersion coating. The addition of HAp aims to enhance the biocompatibility and bioactivity of the scaffold. The variable observed in this study is the agitation time for

the HAp dispersion coating, which was set at 0.5, 1, and 2 hours. The influence of agitation time on the bioactivity and mechanical properties of the scaffold was evaluated through immersion testing in simulated body fluid (r-SBF), swelling testing, visual observation using optical microscopy, SEM & EDS analysis, and dynamic compression testing. The immersion test results revealed that the PLA/HAp scaffold exhibited six times higher bioactivity compared to the PLA scaffold, with the optimal condition being 1% w/v HAp-1 hour. Apatit mineral deposition occurred during a seven-week immersion in r-SBF, while PLA color change was observed from the third to fourth week. SEM & EDS analysis of the scaffolds immersed in r-SBF for seven weeks showed larger apatit deposition on the PLA/HAp samples, the appearance of surface porosity in the scaffold, and surface cracking. Swelling testing demonstrated an increase in swelling ratio with longer agitation time, indicating improved hydrophilic properties of the scaffold. However, longer agitation time was also associated with a decrease in the self-fitting ability of the scaffold. The PLA scaffold endured six cycles of compression and recovery before failure, with a recovery rate of 97-99%. In contrast, the PLA/HAp scaffold failed after two cycles of compression and recovery, with a recovery rate of 90-91% due to HAp intrusion into the strut cross-section. In summary, adding HAp to PLA-based scaffolds enhances biocompatibility and bioactivity. The optimal condition is 1% w/v HAp-1 hour, providing a promising solution for regenerative medicine and tissue engineering applications.