Observed of Change in the Hardness of Ni-Cr alloy used to Dental Selective Laser Melting System

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Statement of Purpose:

Many laser-related application technologies have been developed because lasers have the ability to process materials through the concentration of energy(Zhengying W., The International Journal of Advanced Manufacturing Technology, 2003; 21: 644-648.). In recent years, a selective laser melting (SLM) processing has been introduced to the dental industry that has the advantage of reducing the manufacturing time for metal structures by stacking a virtual 3D CAD model created by a computer without the use of processing tools using metal powder(Ding Y., Robotics and computer-integrated manufacturing, 2004; 20: 281-288.)(Osakada K., International Journal of Machine Tools and Manufacture 2006; 46: 1188-1193.).

When a laser beam is radiated to a metal, some of it is reflected from the surface of the metal, and the rest of it is absorbed in the metal. Only that which is absorbed is used for material processing. The amount of laser beam absorbed in the surface of the metal can differ depending on the wavelength of the laser beam and the electrical conductivity of the metal. The absorbed part is changed into heat energy from the metal surface, thereby producing an important heat source for laser processing. When a laser heat source connected to a laser beam is irradiated to the surface of a metal in the predetermined axis direction, only the local layer of the surface is heated by the thermal conductivity through the inside of the metal, while the heat at the surface layer is rapidly cooled by the base structure as the laser beam continues the irradiation. This cooling process is called self-quenching. When the base metal is melted by the laser radiation, the base material around the fusing zone is heated quickly to a very high temperature, followed by rapid cooling again. The place where change occurs due to the laser fusing heat is divided into the following three parts: fusing zone, heat-affect zone, and base metal. The properties of the base material around the fusing zone are locally and considerably changed. In particular, the fusing zone and the surrounding heat-affect zone experience changes in microstructure and hardness at the penetrated fusing zone due to the rapid cooling. In previous laser SLM-related studies, fusing behavior is affected directly depending on the laser process conditions, such as metal powder type and laser output, scanning speed, and scanning interval.

This study reviewed the change in hardness according to the penetration depth in the laser fusing zone to an Ni-Cr alloy.

Methods:

Materials; Noritake Super (Noritake Dental Supply Co, Limited, Japan), which are commercialized Ni-Cr alloys for dental use, were employed for specimen manufacture.

Table 1 Chemical composition of the dental alloys

Alloys	Ni	Cr	Mo	Ga
Noritake Super	59.6	23.5	9.22	0.46

The laser was irradiated to the center of the specimens under the same condition, with an output of 60 W, pulse duration of 10 ms, and 5 Hz frequency set in the Nd:YAG Laser (Gallieo, Manfredi, Italy), and the condition of the spot diameter was 0.5 mm. In order to measure the laser penetration depth, the fusing zone was cut in half using a metal cutting machine (Sapcom, Hyunyang co., Korea) to see the cross-section. To observe the hardness of the alloys for dental use irradiated by a laser. Hardness measurement was conducted for 10 seconds with a 200 g load using a micro vickers hardness tester (HM112, Mitutoyo, Japan).

Results:

Figure(1) shows the hardness depth profiles according to laser beam irradiation. In all groups, the hardness depth profiles in the laser fusing zone and heat-affect zone had larger values than that of the base metal. In addition, the hardness values in places beyond the fusing zone and the heat-affect zone were measured as being quantitatively lower.

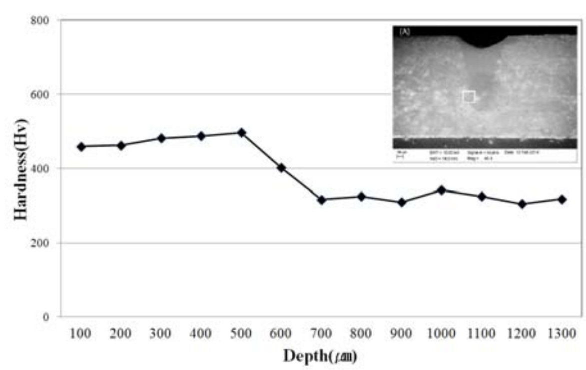

Figure 1. Comparison of hardness depth profiles at 100 ㎛ from cast surface to 1300 ㎛ in depth

Conclusions:

This study reviewed hardness change according to penetration depth in the laser fusing zone as an Nd:YAG laser was irradiated to an Ni-Cr alloy. As a result, this study found the following conclusions. High hardness was achieved because the microstructure of the base metal was modified due to the laser heat source. It was verified that the fusing zone had the characteristics of amorphous alloys, which have better properties than crystalline metal due to the self-quenching caused by laser irradiation.