Development of Dental Scaler Tip Mold with Powder Injection Molding Process

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Abstract

With the capability of net shaping for complex 3D geometry, powder injection molding (PIM) is widely used for automotive parts, electronics and medical industry. In this study, an ultrasonic dental scaler tip produced by machining process was redesigned for the PIM process. An injection mold was designed and machined to produce the dental scaler tip by the PIM process.

Keywords : Dental Scaler Tip, Powder Injection Molding(PIM), Injection Mold, Mold Design

1. Introduction

In dental clinic, an ultrasonic scaler tip is used as scaling implement [1]. The scaler tip vibrates at high frequency for removing tartar from the teeth surface and for dental operations. The scaler tip shown in Fig. 1 has been manufactured by machining process. Machining process has an advantage in accuracy, but is not adequate to mass production due to a high cost and a long manufacturing time, especially for a complex 3D shape [2]. It is not competitive for the production of small parts such as the scaler tips. In this study, the PIM process was examined as a substitute for machining process for the dental scaler tip. The dental scaler tip was redesigned properly for the PIM process. An injection mold was designed and machined to mold the scaler tip with high accuracy and complex functionality [3, 4].

2. Experimental and Results

2.1. Redesign of the dental scaler tip

In this study, the dental scaler tip was redesigned for the PIM process. In order to keep the basic requirements of the scaler tip, the thickness at the inlet of the water supply must be kept for the screw fastening. For preventing the scaler tip from rotation in the assembled state, the cross-section of the upper stem part must be kept. Water is supposed to flow through a nozzle at the bottom of the edge. The original design of the scaler tip is shown in Fig.2(a). The second design shown in Fig.2(b) was proposed to make the nozzle by a slim curved pin. After several modifications, the final design was made as shown in Fig.2(c). The pin for nozzle was not located at the center of the pin.

2.2. Mold design

As shown Fig.3, the initial mold deign was made to use a slide core. However, in the initial design there was a significant problem for the main core pin bending. The main core pin was too slim to keep it straight during molding. In the final design, two mirrored cavities of a half of the scaler tip were machined in two facing sliding blocks. Runners and gates were also machined on both blcoks as shown in Fig.3. In the design, the slim core pin was easily kept straight. The two sliding blocks were moved by angular pins. In the design, it was easy to change product shape only by changing the sliding blocks having different cavity as shown in Fig.3. Before completing the mold making, the flow pattern and the deformation of the core pin was checked by a CAE analysis, and the result was reflected to the mold design. The detail of the CAE analysis is described in a separate publication [4].

Since the PIM feedstock is brittle and rheologically sensitive to temperature change, sprue and runner are designed bigger than in plastics molding. The cross-section of runner was designed as a circular shape for minimum heat loss. The diameter of runner is 7 mm. With a CAE analysis, the diameter of gate was designed to 0.3 mm in order to prevent binder separation around the gate. A gate was located in the lower stem part of the scaler tip to minimize the deformation of the main core pin. The main core pin is surrounded by a sleeve pin for part ejection. When the mold is opened, the two sliding blocks are separated apart. Then, molded part is held by the main core pin at the center of the stem. For part ejection, the sleeve pin pushes the bottom of the stem part of the scaler tip to the upright direction.

2.3. Injection molding process

Table 1 shows powder material and composition of the feedstock in the study. The powder for the scaler tip was stainless steel powder, STS316L, manufactured by ATMIX. Binder used in the experiment was a wax based binder with EVA and CW. For the injection molding experiment, a 55-ton injection molding machine (Boy 55M, Germany) was used. An abrasion-resistant screw was equiped in the machine. In order to check the mold, a short shot test was done with LDPE. In the short shot test, the filling balance to both cavities was examined. After examining the filling balance, a short shot test was done for the PIM feedstock as shown in Fig.4. Even in the short shot test for the PIM feedstock, a satisfactory filling balance was achieved. The injection molding experiment was carried out with the conditions in Table 2. As a result of injection molding, a discoloration appeared around the gate and flashings at the air vent in the PIM samples as shown Fig.6 while there was no such problem in the LDPE samples. The discoloration around the gate seemed to be caused by the binder separation. The flashing at the air vent seemed to be caused by a low viscosity of the PIM feedstock. However, the flashing was very thin so that it could be easily removed in the green state. If the flashing was not removed in the green state, it remained in the sintered sample as shown in Fig.6. The discolored part around the gate left an uneven surface as shown in Fig. 5.

3. Summary

The ultrasonic dental scaler tip produced by machining process was redesigned for the PIM process. The injection mold was designed and examined for the PIM process of the scaler tip. As results, conclusions were made as below.

1. The PIM process turned out to be an excellent substitute for machining process to manufacture the ultrasonic dental scaler tip with respect to dimensional stability, accuracy and productivity.
2. The mold design with 2 sliding blocks containing cavities, runners and gates worked fairly well, but left a minor problem such as an air vent causing a flashing to the part.
3. It is desirable to adjust the gate size and the composition of the feedstock to prevent the binder separation around the gate.

4. References

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Table 1. Powder and composition of the feedstock

	Powder	Binder			
	STS316L	EVA	PW	CW	SA
Fraction	50 vol%	20 wt%	69 wt%	10 wt%	1 wt%
Density (g/㎤)	7.850	0.940	0.90	0.97	0.845

Table 2. Injection molding conditions.

Melt temp. (℃)	155	Injection time (sec)	0.46
Mold temp. (℃)	40	Holding pres., (MPa)	3
Injection speed (mm/s)	30	Holding time (sec)	0.46

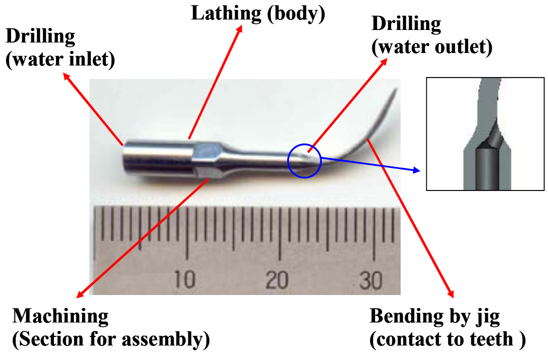
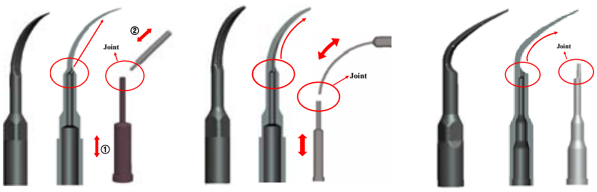


Fig. 1. A dental scaler tip manufactured by machining process.



(a) Type-A (a) Type-B (a) Type-C

Fig. 2. Product redesign for dental scaler tip.

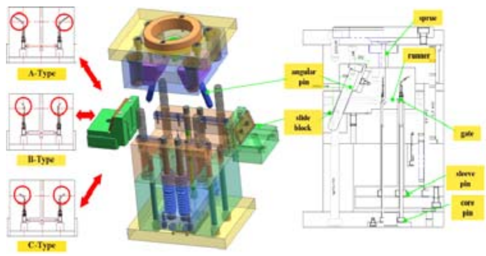


Fig. 3. Detail scaler tip mold of 2D/3D drawing.

Fig. 4. Short shot experiment of dental scaler tip using the PIM feedstock(STS316L).

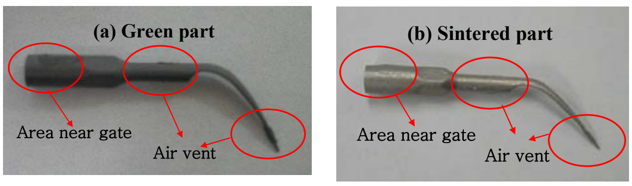


Fig. 5. Detail view of defects after powder injection molding and sintering.