

The Effect of Elastomeric Impression Materials and Gingival Sulcus Widths on the Dimensional Accuracy of Stone Die

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Abstract

The aim of this study was to compare the dimensional accuracy of replicating stone dies poured from four elastomeric impression materials taken on three clinically simulated sulcular widths (0.1, 0.2 and 0.4 mm). Four elastomeric impression materials [Vinylpolyethersiloxane (Identium®), Hydrophilic polyvinylsiloxane (Hydrorise), Hydrophobic polyvinylsiloxane (Variotime®) and Soft polyether (Impregum™ Penta Soft)] were used to make 12 impressions of metal die of each sulcular widths by double-mix, single impression technique. Thus, a total of 144 impressions were made. The impressions were disinfected and left for 30 minutes. Then, Type IV dental stone (Vel-Mix™) were mixed and carefully vibrated into impressions. When dies stone completely set, the dies were removed and areas beyond finish line were trimmed. The diameter of gypsum dies at finish line were subjected to measurement in B-L as well M-D direction using measuring microscope with linear resolution 0.001 mm, 30X magnification. The mean diameter of dies stone were subtracted from metal die diameter. Subsequently, percent distortion of dies stone were calculated to represent an accuracy. The data was statistically analyzed by Two-way ANOVA and Tukey's HSD test. The results showed that there was statistically significant interaction between sulcular widths and impression materials on accuracy of die stone ($F=6.486$, $P<.01$). Vinylpolyethersiloxane has been revealed the significantly lower distortion of die stone at 0.2 and 0.1 sulcus width. When considering the distortion among three sulcular widths, the wider sulcular width (0.4 mm) provides more accurate die stone than narrower sulcus. It could be concluded that Vinylpolyethersiloxane gave the most accurate die stone of all materials tested. This material may be alternative to the polyvinylsiloxane and polyether in impression making for definitive cast and dies.

Keywords: Dimensional accuracy/ Elastomeric impression materials/ Gingival sulcus widths/ Distortion/ Die stone

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Introduction

Impression making is the critical step in the fabrication of indirect restorations. After final impression were done, the impressions were poured with gypsum product to form the definitive cast and die. The master cast and die must be accurately reproduced impression detail, dimensionally stable under conditions of use and storage, minimal response to temperature changing. It should also have a smooth and hard surface to withstand abrasion during laboratory procedure.¹ So, the accuracy of master cast and die is a function of the completeness and accuracy of the impression.² Accuracy and completeness of impression are dependent on marginal thickness of restoration and physical properties of materials.³

Polyvinylsiloxane (PVS) and polyether (PE) are commonly used for final impression in restorative dentistry. Polyvinylsiloxanes have a great detail reproduction together with dimensional stability because of no by-product

formation. It can be poured within 1-2 weeks after making impression with multiple times.⁴ However, the disadvantages of PVS are hydrophobic nature arising from chemical structure which contains hydrophobic aliphatic hydrocarbon group around the siloxane bond and moderately high contact angle. These make a greater tendency to entrap air bubbles within die stone. Moreover, its polymerization reaction was inhibited by sulfur compound in latex gloves and the oxygen layer on the composite surface.⁵ The new formula of PVS has been added nonionic surfactant to improve wettability, reduce contact angles and also pour die stone or cast without incorporating voids. There is scientific evidence revealed that the newer hydrophilic material performs no better than the original formulations in wettability for pouring die.⁶ In addition, the clinical usage of this material still need dry field preparation that means the material remains hydrophobic.

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Polyethers are hydrophilic with good wettability, allowing them to be used in moist environment.⁷ It is excellent surface detail reproduction and dimensionally stable. It allows multiple pours of accurate casts for 1 to 2 weeks after impressions are made without tearing of the impression. This material becomes rigid when set and may be more difficult to remove from mouth than polyvinyl siloxanes. The new generation of polyether named “soft polyether” has been improved taste, elasticity with advancing mixing system to achieve homogenous void-free material.⁸ Nonetheless, it is likely to absorb water due to its hydrophilic nature. For this reason, it should not be submerged in water for a long period of time and strict disinfection protocol should be considered to prevent swelling of material which leads to distortion. Recently, the hybrid material between polyvinylsiloxane and polyether so-called “vinylpolyethersiloxane” has been developed that possess optimized elastomeric properties with high resilience, high tear resistance and balanced elasticity.⁹ Previous study¹⁰ found that vinylpolyethersiloxane produced dies stone as accurate as polyvinylsiloxane and polyether in Bucco-Lingual and Mesio-Distal dimension. Whereas, polyvinylsiloxane were shown significantly shorter die stone than master die. Some controversy study¹¹ revealed that there was significant difference in mean dimensional change of die stone among vinylpolyethersiloxane, polyvinylsiloxane and polyether at immediately poured time.

The aim of this present study was to test and compare the dimensional accuracy of dies stone poured from four elastomeric impression materials in three clinically simulated sulcular widths after sprayed with disinfecting solution. The null hypothesis was that there would be no significant difference in an accuracy of dies stone among four elastomeric impression materials at three sulcular widths.

Materials and method

1. Testing model construction

The testing model was designed by software PLM NX version 11.0 and fabricated by milling machine (Mikron model VCE 750, Machining Center, Germany) using Computed Numerical Controlled technique. Model used in this study was adapted from prior research¹² by designing finish line and undercut area to simulate clinical tooth

preparation. The schematic diagram of testing model was illustrated in figure 1. The component of testing model are 1.1) a sulcus former which is 8 mm cylindrical steel rod with 2 mm long slope divergence to 8.4 mm diameter end 1.2) three metal dies were prepared to accurately fit the base tool. The metal dies were machined to simulate abutment teeth with 1 mm subgingival chamfer finish line and undercut area. The different diameter of metal dies at finish line (7.6,8.0 and 8.2mm) generated varying sulcular widths 0.4,0.2 and 0.1 mm (Figure 2 A-D). Four reference points on each metal die were delineated by rotating of point through 90 degree about the origin in clockwise direction. 2) cylindrical base tool 26 mm height, diameter 16 mm width with 8 mm central hole were drilled. The other side of base tool were reduced to diameter 14 mm width 3.5 mm length, then followed by diameter 11 mm width 2 mm length and final 2 mm length with 12 mm in diameter 3) supporting ring 12 mm height with diameter 14 mm was placed on shoulder of base tool 4) artificial gingiva was prepared by mixing 7 grams of reversible hydrocolloid powder with 10 milliliters of distilled water over the hotplate stirrer at 65°C then filled in the space between supporting ring and sulcus former, the excess material was pressed flush with thin cover glass. After cooling down of artificial gingiva, replaced the sulcus former rod by metal die (Figure 3 A-D) 5) impression material tested with light and heavy body 6) impression stand.

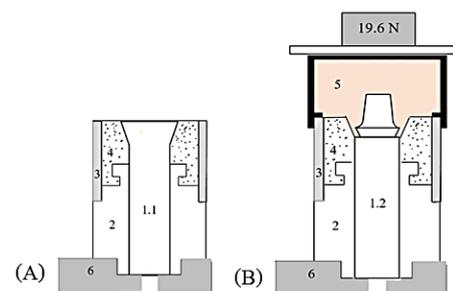


Figure 1 (A) Axial section through steel device for production of artificial gingiva tissue (reversible hydrocolloid) and (B) axial section through impression of metal die in tray.

- 1.1 = sulcus former rod with 2 mm long slope divergence to upper surface, 0.4 mm wider than main part
- 1.2 = metal die simulated prepared tooth with chamfer finish line located 1 mm within sulcus,
- 2 = undercut part of base tool,
- 3 = supporting steel ring,
- 4 = artificial gingiva,
- 5 = elastomeric impression materials,
- 6 = impression stand

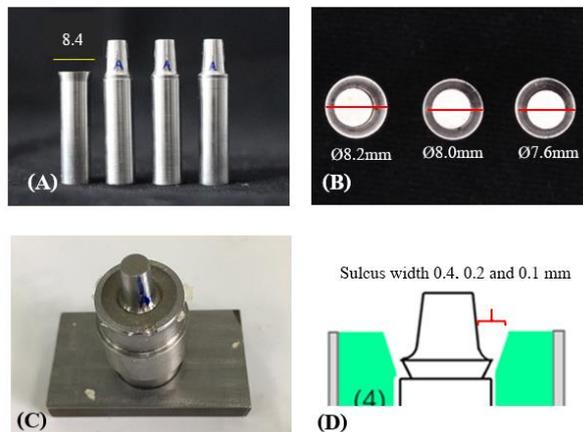


Figure 2 (A) Sulcus former rod with 8.4 mm end diameter (B) three different diameter of machined metal dies with 1 mm subgingival chamfer finish line and undercut area (C) sulcus width of testing model (D) schematic diagram of sulcus widths (axial view)

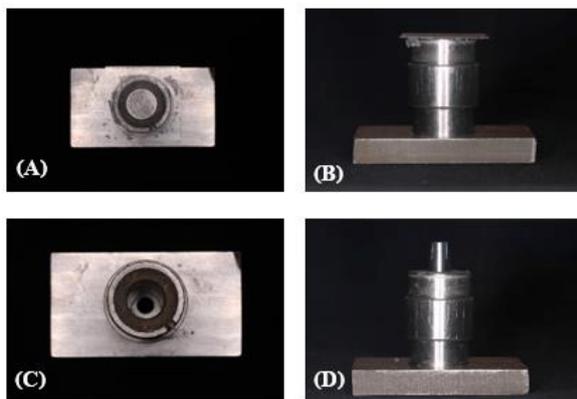


Figure 3 (A) Artificial gingiva (hydrocolloid solution) was filled in the space between sulcus former rod and supporting ring (B) excess material was pressed flush with thin cover glass (C) generated space after sulcus former rod was pushed out (D) metal die replaced the sulcus former rod to form simulated gingival sulcus

2. Impression taking

Impressions were made using four elastomeric impression materials (Table 1). For each material, 12 impressions were made for each of sulcular width using double-mix, single-impression technique resulting a total number of 144 specimens. The light consistencies were mixed through mixing tip fitted to cartridge materials and dispensing gun. The light body was injected through plastic delivery tip into sulcus and covered metal die within 60 sec from mixing. While the heavy consistencies were mixed by automatic mixing unit (Pentamix™ lite, 3M ESPE) and inserted into perforated impression tray. The remnant of light body was placed over the heavy body, then seating the impression tray until contact the upper rim of supporting ring. Impression was loaded with 2 Kg (19.6 N) of metal plummet. The materials were allowed to set at room temperature of $23 \pm 2^\circ\text{C}$ for 10 min (Figure 4 A-D). After setting, the impressions were separated from metal die then rinsed with running tap water to simulate the rinsing of blood and saliva. Afterward, the impressions were gently air-dried and sprayed with 2.5% glutaraldehyde disinfectant (Cavicide™, Kerr Dental, Switzerland). The disinfected impressions were stored at room temperature for minimum 30 min before thoroughly rinsing and air streaming. The freshly mixed artificial gingiva was prepared and took the place of previously used artificial gingiva before the new impression was done.

Table 1 Elastomeric impression materials used in this study

Type	Brandname	Manufacturer	Batch No.
Vinylpolyethersiloxane (VPES)	Identium® Heavy	Kettenbach GmbH, Germany	80721-06
	Identium® Light		80011
Hydrophilic polyvinylsiloxane	Hydrorise Heavy body	Zhermack S.p.a., Italy	0809151
	Hydrorise Light body		080901
Hydrophobic polyvinylsiloxane	Variotime® Dynamix heavy tray	Kulzer GmbH, Hanau Germany	KA10271
	Variotime® Light flow		KA10110
Soft polyether	Impregum™ Penta™ H Duosoft	3M ESPE AG, Seefeld, Germany	254391
	Impregum™ Penta™ Garant L duosoft		254655

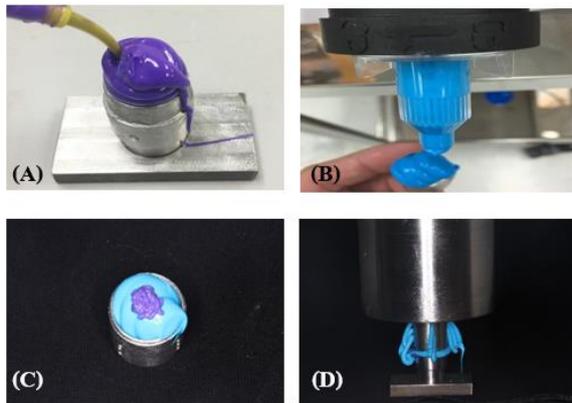


Figure 4 (A) Injection of light body material through plastic delivery tip into sulcus and over metal die (B) heavy consistencies were mixed by automatic mixing unit and loaded into perforated impression tray (C) remnant of light body in syringe was placed over heavy body (D) seating impression tray over metal die with 2 Kgs of metal plummet

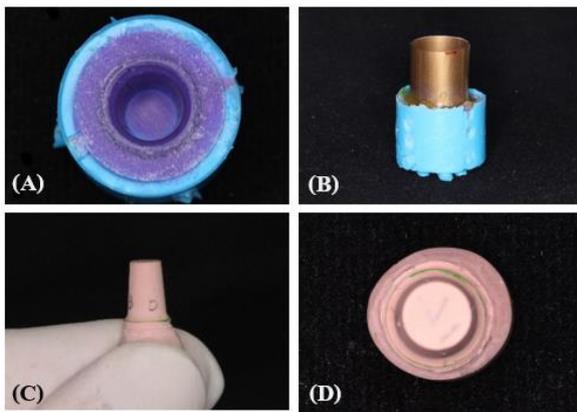


Figure 5 (A) Disinfected impression ready for pouring die stone die (B) boxing impression with plastic straw (C) trimming die stone at area under finish line (D) Top view of die stone

3. Pouring the dies stone

The impressions were boxed with 1-inch length plastic straw and sealed with sticky wax to form die stick. Each impression was cast with type IV dental die stone (Vel-Mix™, Kerr Dental, Thailand). The gypsum slurry was mixed with the powder: water ratio of 100 g: 22 ml. The die stone was mixed under Vacuum mixer (Whip mix Vac-U mixer, Louisville, KY) for 20 sec and carefully vibrated into impressions by power vibrator (Denstar*500, Daegu, Korea) then the dies stone were left to fully set for 1 hour. When dies stone completely set, the resulting dies stone were separated from impressions with caution then trimmed area beyond finish line to make it clearly located the boundary of finish line (Figure 5 A-D).

4. Evaluation of an accuracy of dies stone

The accuracy of dies stone were indirectly assessed by comparing to the diameter of metal die at finish line level (Figure 6 A-B). The diameter of each die stone was measured three times in Bucco-Lingual and Mesio-Distal dimension using measuring microscope (Nikon® measurescope 20, Japan). The mean diameter was considered to be the reading for that specimen then the distortion (%) of each die stone was calculated from the equation

$$\text{Distortion (\%)} \text{ of each stone die} = \frac{(\text{mean metal die diameter} - \text{mean stone die diameter}) \times 100}{\text{mean metal die diameter}}$$

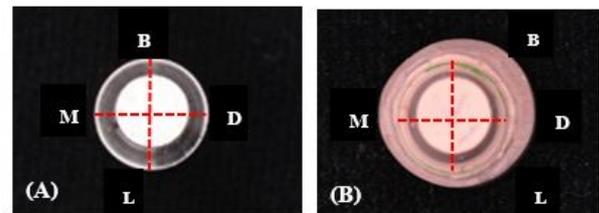


Figure 6 (A) Four reference points of metal die with marking were used to compare mean diameter of die stone at level of finish line (B) mean diameter of die stone was measures at the same reference points as metal die.

The experimental error was determined by measuring the diameter of same stone die 10 times and calculating the coefficient of variation [CVs = (SD/Mean) × 100]. The CVs indicates the reliability for measurement. The percent distortion of stone dies in relation to metal die among four impression materials at three sulcular widths were analyzed by Two-way ANOVA at significant level of 95%. Where significant difference were found, Tukey's HSD test was used for comparison of individual means.

Results

The result of Two-way ANOVA indicated that there were significant differences among the impression materials, sulcular widths, and their interactions ($P < 0.05$). The mean percent distortion of stone dies and standard deviation obtained from four impression materials among three sulcular widths were shown in figure 7. For sulcular widths 0.4 mm,

vinylpolyethersiloxane showed the least percentage of distortion in relation to metal die whereas hydrophilic polyvinylsiloxane showed the greatest distortion. However, the significant difference had not been detected among materials. At 0.2 mm sulcular width, vinylpolyethersiloxane exhibited significantly least distortion among material tested. Whereas the other materials showed significantly greater value. Within 0.1 mm sulcular width, vinylpolyethersiloxane had been also revealed the least percent distortion of stone die. Hydrophilic polyvinylsiloxane showed the greatest percent distortion but

there was no significant difference with hydrophobic polyvinylsiloxane and soft polyether. Post hoc test for multiple comparison found that there were statistically significant differences of stone die distortion among materials tested and various sulcular widths.

When considering effect of sulcular width, the percent distortion of wider sulcus was considerably lower than narrower sulcus. The coefficient of variance was 0.02% indicating the reliability of measurement.

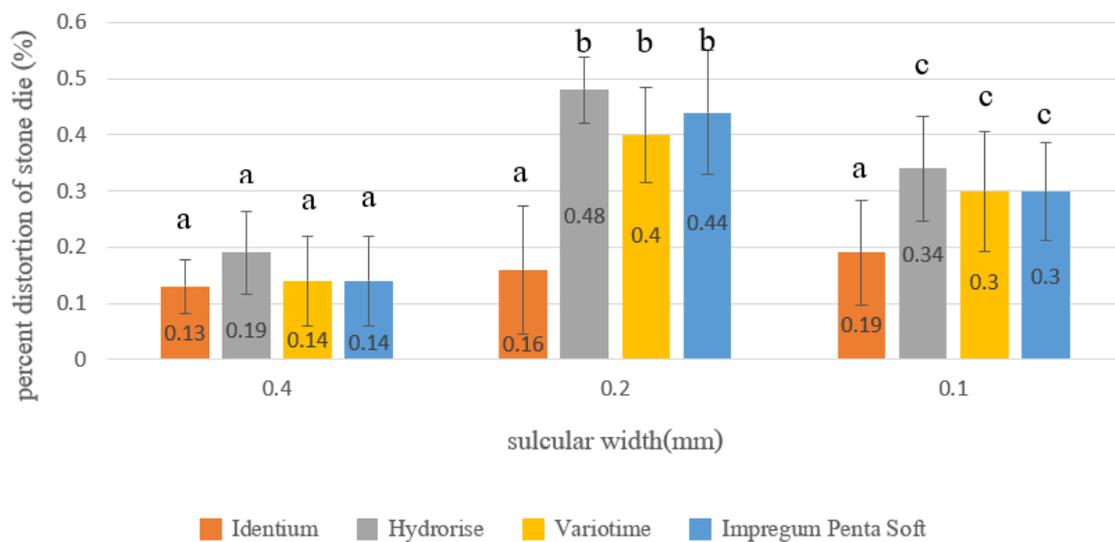


Figure 7 Mean difference in percent distortion of stone die among four impression materials in three sulcular widths. Vertical bars indicates SDs. Groups with same superscripted letter indicate no significant differences between impression materials at $P < 0.05$

Discussion

The testing model used in this paper was modified from earlier study¹² which designed non-undercut abutment and prepared 0.05, 0.1 as well 0.2 mm sulci. These features are not fully mimic natural gingival sulcus. Thus, this study fabricates metal die with finish line and undercut area to simulate clinical tooth preparation. Furthermore, this research choose sulcus width 0.4, 0.2 and 0.1 mm for investigation because 0.4 mm sulci is a space available immediately after retraction cord removal. The 0.2 mm sulci is developed after 40s, this sulcus width is considered to be the critical sulcular width to provide sufficient material thickness preventing

tearing or distortion.¹³ Whereas 0.1 mm sulci would be found at transitional line angle and interproximal area due to improper gingival displacement technique or delayed taking impression.¹²

The null hypothesis that elastomeric impression material types tested in different sulcular widths would not influence the accuracy of stone die, is rejected. The percent distortion of stone die ranged from 0.13%-0.48%. The distortion was considerably lower when sulcular width is wider. Although, all elastomers underwent dimensional change due to polymerization shrinkage, loss of volatile by-

product or lack of elastic recovery.¹¹ The percent distortion of stone die made from vinylpolyethersiloxane had not been shown significant difference among sulcular widths. The reason why this material behaved distinctively could be related to their chemical formula which are crosslinked by organohydrogen polysiloxane via platinum catalyst. The crosslinking reaction appears to be no volatile byproduct released.¹⁴ Moreover, the filler system that manufacturer incorporated into their structure which are nano silica agglomerates and silianized microquartz enable the balanced stability as well as elastic quality of this material.⁹ This was in agreement with Chen et al.¹⁵ in which an increased proportion of filler component may increase the accuracy of material. At the same time, significant difference among material types had not been detected at 0.4 mm sulcular width. Whereas sulcus 0.2 and 0.1 mm were significantly different. This result was supported by a study of Laufer et al.¹⁶ who found that the distortion of impression materials in sulcular width greater than 0.2 mm could not be detected the difference.

During removal impression from the mouth, the materials are subjected to both compressive and removal force. The removal force is likely to be greater than compressive force in the presence of undercut area, sharp line angle and interproximal spaces.¹⁷ Thus, tensile elastic recovery could be more clinical relevant in explanation the accuracy of impression material. Considering that tensile properties affected to dimensional accuracy of elastomeric impression material, study of Re et al.¹⁸ found that impression material with a tensile strength at break/ yield strength ratio (TSb/YS ratio) sufficiently close to 1 should probably be preferred. This ratio implied the material's ability to withstand maximum tensile stress without permanent deformation. Especially, concerning the light body employed in thin proximal and crevicular area. The TSb/YS ratio of Vinylpolyethersiloxane was 0.669 whereas Soft polyether (Impregum Penta Duosoft) and hydrophilic polyvinylsiloxane (Hydrorise) were 0.644 and 0.587 respectively. This was comparable to present study that Identium showed less distortion of stone dies following by Variotime, Impregum Penta Soft and Hydrorise in both sulcular width 0.2 and 0.1 mm. Moreover, previous studies^{19,20} on

mechanical properties of elastomeric impression materials revealed that the stone model made from vinylpolyethersiloxane provided more accuracy than soft polyether and polyvinylsiloxane. This is plausible that it had been combined unique features of parent materials; hydrophilicity of polyether along with high elastic recovery and tear resistance of polyvinylsiloxane.

When comparing the distortion of stone die among sulcular widths, the distortion at narrower sulcular width was considerably larger than the wider sulcular width. The possible explanation was that coupling effect of both permanent deformation during separation the impression from undercut and narrow space around abutment and dimensional change during setting.²¹ Interestingly, the percent distortion of stone die at sulcular width 0.2 mm was larger than 0.1 mm. This was in agreement with previous findings which stated that physical properties of impression material could not be predicted accurately in narrow sulcus.²² Another study²³ reported that an increased material thickness caused a greater distortion. The distortion of increased material thickness occurred by thermal change from room temperature to oral temperature while making impression, then reduced to room temperature while pouring stone die leading to thermal contraction of material. The synergy between thermal contraction and polymerization shrinkage would have resulted in greater distortion of stone die at 0.2 mm sulcular width. This study evaluated dimensional accuracy of die stone in terms of percent distortion which were in range between 0.13-0.48% for all sulcular widths. To our knowledge, there was no standard for percent distortion of die stone whereas ADA specification no.25²⁴ recommends a setting expansion of type IV dental stone up to 0.1% at 2 hours after mix. Comparing the results of this study with ADA cannot be made due to differing specimen preparation and determination method. However, the replicating dies stone which poured from all four elastomeric impression materials did not reveal value beyond arbitrary estimation of 0.4% deformation limit.²⁵ Thus, the material tested in this study could be clinically acceptable for giving accurate die stone. In case of precisely fit of indirect restoration needed, the Vinylpolyethersiloxane may be considered to be an alternative to the polyvinylsiloxane and polyether in making final impression.

Conclusion

Both sulcular widths and material types have an effect on dimensional accuracy of stone dies. The percent distortion of stone die was greater when sulcular width was narrower. Vinylpolyethersiloxane revealed the more accurate stone die than other materials when sulcular width was 0.2 mm or narrower. At sulcular width 0.4 mm, all materials did not show the significant difference in stone die distortion.

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ผลของวัสดุพิมพ์แบบอีลาสโตเมอร์และความกว้างของร่องเหงือกต่อความเที่ยงตรงเชิงมิติของแบบถอดพลาสติกเรซิน

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บทคัดย่อ

การศึกษานี้มีวัตถุประสงค์เพื่อเปรียบเทียบความเที่ยงตรงเชิงมิติของแบบถอดพลาสติกเรซินที่มาจากวัสดุพิมพ์แบบอีลาสโตเมอร์ไวไนล โพลีเอเทอร์ไซลอคเซน ไฮโดรฟลิค โพลีไวไนลไซลอคเซน ไฮโดร โฟบิก โพลีไวไนลไซลอคเซน และ ซอฟท์โพลีเอเทอร์ในความกว้างร่องเหงือกจำลอง 3 ขนาด 0.1 0.2 และ 0.4 มิลลิเมตร รอยพิมพ์ทั้งหมดจำนวน 144 รอยพิมพ์ ($n=144$) ถูกสร้างจากการพิมพ์แบบถอดโลหะจำลองฟันหลัก โดยใช้เทคนิคการพิมพ์วัสดุพิมพ์ชนิดหนืดมากและชนิดหนืดน้อย 1 ชั้นตอน รอยพิมพ์ทั้งหมดถูกนำมาทำแบบถอดด้วยพลาสติกเรซินชนิดที่ 4 เมื่อแบบถอดแข็งตัวเต็มที่จึงนำมาถอดส่วนคอคได้เส้นสิ้นสุด จากนั้นนำไปวัดค่าเส้นผ่านศูนย์กลางในแนวใกล้แก้ม-ใกล้ลิ้นและใกล้กลาง-ใกล้กลางด้วยกล้องจุลทรรศน์ วัดระยะคำนวณหาเปอร์เซ็นต์การบิดเบี้ยวของแบบถอดพลาสติกเรซินเพื่อแสดงถึงความเที่ยงตรงของแบบถอด ข้อมูลที่ได้ถูกนำมาวิเคราะห์ด้วยการวิเคราะห์ความแปรปรวนแบบสองทาง ผลการศึกษาพบว่าขนาดความกว้างร่องเหงือกและชนิดของวัสดุพิมพ์แบบต่างมีอิทธิพลร่วมอย่างมีนัยสำคัญทางสถิติต่อความเที่ยงตรงของแบบถอดพลาสติกเรซิน ($F = 6.486, P < .01$) โดยแบบถอดพลาสติกเรซินที่มาจากวัสดุพิมพ์แบบไวไนล โพลีเอเทอร์ไซลอคเซนจะมีเปอร์เซ็นต์การบิดเบี้ยวน้อยกว่าวัสดุชนิดอื่นอย่างมีนัยสำคัญที่ความกว้างร่องเหงือก 0.2 และ 0.1 มิลลิเมตร เมื่อพิจารณาความกว้างร่องเหงือกทั้งสามขนาด พบว่าความกว้างร่องเหงือก 0.4 มิลลิเมตรแบบถอดพลาสติกเรซินจะมีเปอร์เซ็นต์การบิดเบี้ยวน้อยกว่าความกว้างร่องเหงือก 0.2 และ 0.1 มิลลิเมตร อาจสรุปได้ว่าวัสดุพิมพ์แบบไวไนล โพลีเอเทอร์ไซลอคเซนนำมาทำแบบถอดพลาสติกเรซินได้มีความเที่ยงตรงมากที่สุดและอาจใช้แทนวัสดุพิมพ์โพลีไวไนลไซลอคเซนและโพลีเอเทอร์ในการทำรอยพิมพ์ขั้นสุดท้ายได้

คำชี้แจง: ความเที่ยงตรงเชิงมิติ/ วัสดุพิมพ์แบบอีลาสโตเมอร์/ ความกว้างร่องเหงือก/ การบิดเบี้ยว/ แบบถอดพลาสติกเรซิน

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