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# Effect of the Impression Margin Thickness on the Linear Accuracy of Impression and Stone Dies: An In Vitro Study

**Y. G. Naveen · Raghunath Patil**

**Abstract** The space available for impression material in gingival sulcus immediately after the removal of retraction cord has been found to be 0.3–0.4 mm. However after 40 s only 0.2 mm of the retracted space is available. This is of concern when impression of multiple abutments is to be made. Hence a study was planned to determine the minimum width of the retracted sulcus necessary to obtain a good impression. Five metal dies were machined to accurately fit a stainless steel block with a square cavity in the center with spaces, 1 mm deep and of varying widths (0.11–0.3 mm) away from the block. Polyvinyl siloxane impressions were made and poured using a high strength stone. Using traveling microscope, length and widths of abutment, impression and die were measured and compared for linear accuracy and completeness of impression. Results showed 1.5–3 times greater mean distortion and larger coefficient of variance in the 0.11 mm group than in the wider sulcular groups. ANOVA test for distortion also showed statistically significant differences ($P < 0.05$). 75 % of impressions in 0.11 mm group were defective compared to less than 25 % of impressions in other width groups. It is not always possible to predictably obtain accurate impressions in sulcus width of 0.11 mm or lesser. Dimensionally accurate and defect free impressions were obtained in sulcus width of 0.15 mm and wider. Hence clinicians must choose retraction methods to obtain a width greater than 0.35 mm. Further immediate loading of the impression material after cord removal may improve accuracy.

**Keywords** Dies · Impression margins · Sulcular width

## Introduction

In an aesthetic conscious society, there has been greater public awareness of the value of availability of cosmetic dentistry. This has led to an increase in demand for high quality esthetic restoration in fixed prosthodontics, especially with respect to anterior metal ceramic restorations where the metal margins may result in unesthetic appearance.

One of the important factors which contribute to the success of cast restorations is marginal integrity. Although supra gingival finish lines are preferred, most finish lines may be subgingival because of caries extending cervically, tooth fracture, existing restorations, esthetic demands, additional retention, hypersensitivity and abrasion. To achieve good marginal fit and esthetics, the gingival finish line should be recorded in the impression. The inability of most final impression material to adequately displace soft tissue, fluid or debris mandates adequate gingival displacement prior to making impression. Exposing the gingival margin of a preparation is sometimes inadequate for making impression [1]. There are many ways to expose gingival margin, like mechanical retraction, chemicomechanical and surgical methods [2], but one of the commonly used methods, in the clinic is chemicomechanical retraction.

Chemicomechanical retraction of the gingiva is accomplished by placing medicated retraction cord into the gingival crevice. Sulcular space measurements of approximately 0.3–0.4 mm have been recorded immediately after cord removal [3], which is sufficient for making good impression, but it has been observed that rapid closure of

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transitional line angle area of the sulcus to less than 0.2 mm takes place within 40 s [4]. Currently, good impressions of preparations for fixed or removable prosthesis can be obtained with available elastomeric impression materials [5]. The initial setting time for silicone and polyether impression materials ranges from approximately 2–4 min [6]. Some impression material may be displaced from the sulcus as the tissue returns to its original position. This could result in impression with thin unsupported margins that can tear and distort when impression is removed from the mouth or when poured with die stone [7].

If gingival management in a narrow sulcus is insufficient, the ability of an impression material to penetrate into a narrow sulcus area is one of the most advantageous properties for the clinical use of the material. Usually, gingival finish lines are placed at not more than 1 mm depth into the gingival sulcus from the crest of the gingiva. All previous studies have analyzed the flow property, handling characteristics, adaptation to oral structures and accuracy to reproduce surface details of an elastomer. However completeness of impression means ability to penetrate at least a depth of 1 mm in a narrow sulcus. This has not been measured in previous studies.

The purpose of this study was to examine the effect of varying simulated sulcular widths and the resultant impression marginal thickness on the completeness of the impression and the linear dimensional accuracy of the impression and stone die.

## Methodology

A stainless steel block with a square cavity in the center was constructed. Five metal dies were machined to accurately fit the recess. Spaces, 1 mm deep of varying widths (0.11, 0.15, 0.19, 0.22, 0.3 mm) were created between the die and the recess wall. The models simulated prepared abutment teeth surrounded by retracted gingiva with sulci of different widths (Fig. 1). A 1.5 mm thick modeling wax was adapted to die to act as a tray spacer and tray stoppers were created by removing two square shaped pieces of wax on the upper surface of the die. Special tray was fabricated using auto polymerizing acrylic resin and the tray was allowed to polymerize at least 1 day (24 h) before use. Multiple perforations were made with a round bur; tray adhesive was applied to the internal surface of the tray and allowed to dry for 10 min.

A single-stage/double-mix putty wash impression technique was used. A low viscosity poly vinyl siloxane impression material was extruded into a glass slab and mixed with stainless steel spatula using hand spatulation. Mixed material was loaded into injection syringe from which it was injected into the crevice and around the abutment. High
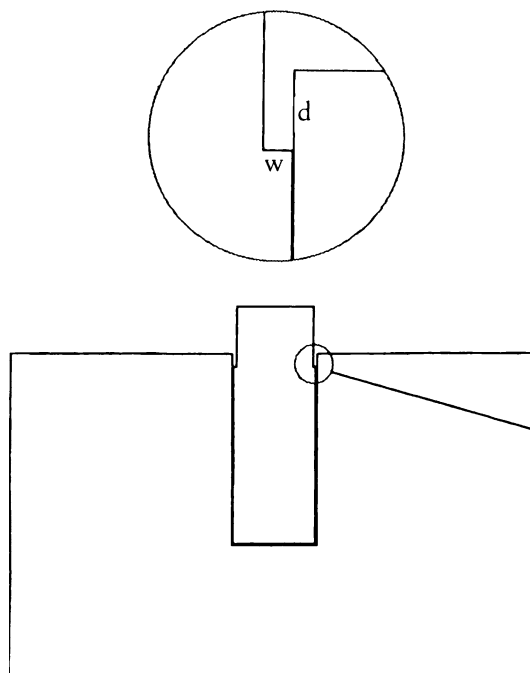


**Fig. 1** Stainless steel abutment within the slot (d = 1 mm, w = 0.11–0.3 mm)
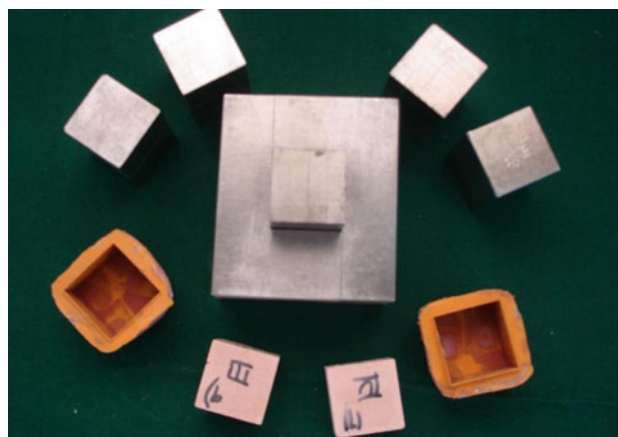


**Fig. 2** Metal dies, impression made and stone dies obtained

viscosity material (putty) was placed in the tray, seated with light pressure, and allowed to remain in place, without loading, at room temperature until the material was set (10 min). Like this 20 impressions were made of each abutment for a total of 100 impressions. One hour after setting of the impression, the impressions were poured using a high-strength stone (Type IV stone). A powder/water ratio of 100 g/22 ml was used. The water and powder were mixed in an automixer under vacuum. The mixture was poured into the impression on a vibrator and allowed to set for at least 1 h before separation. Then stone die was recovered from the impression (Fig. 2).

Measurements were done using traveling microscope with a measurement capability of 1 μm. First, the length and width of each abutment was measured. Then the impressions were measured for extension of the impression that flowed into the crevices at six points and the length and width of impression were measured. Then, the length and widths of die were measured. The experimental error was determined by measuring an impression and a stone die ten times in each direction (width and length) and the coefficient of variation (CV) was calculated.

Although clinicians would be interested in the dimensional distortion of the die as compared with the original abutment, such a comparison encompasses two distortions, that of the impression and that of the pouring of the stone die. Therefore, to define the inaccuracy attributed to the stone pouring alone the distortion was calculated for each die relative to its impression.

The distortion of each impression was calculated as follows:

$$\text{Distortion}\% = \frac{\text{Impression dimension} - \text{abutment dimension}}{\text{Abutment dimension}} \times 100$$

Similarly, the distortion of stone die was calculated as:

$$\text{Distortion}\% = \frac{\text{Die dimension} - \text{Impression dimension}}{\text{Impression dimension}} \times 100$$

The inaccuracies of the impression and the dies for the five different sulcular width groups were compared. Measurements were subjected to one-way analysis of variance (ANOVA) of repeated measures.

## Result

In the present study, the maximum experimental error for measurement of both impression and die was 0.23 % (Table 1).

Impressions with thin margin of 0.11 mm showed maximum mean distortion of 1.24 %, whereas other thicker margins of 0.15, 0.19, 0.22 and 0.3 mm showed a distortion of only 0.52–0.68 % (Graph 1). It can be seen that distortion

for 0.11 mm sulcular width group was almost 1.5–2 times greater than the rest and all other sulcular widths showed almost similar distortion.

There was a larger CV among the 0.11 mm sulcular width group than the other sulcular width group which meant inconsistencies in obtaining good impression and stone dies in 0.11 mm sulcular width group (Graph 2).

One-way ANOVA for impression and stone dies made with varied sulcular widths showed statistically significant difference ($P < 0.05$) (Tables 2, 3). 0.11 mm sulcular width showed the maximum defective impression i.e. 15 defective impressions rest (0.15, 0.19 and 0.22 mm) showed between 3 and 4 defective impression and 0.3 mm sulcular width showed no defective impression at all (Table 4).

## Discussion

Success of retraction cords goes hand in hand with the success in obtaining a good impression. The impression material should flow to the depth of the sulcus otherwise the effort in retracting the gingiva turns out to be a waste. The flow of the impression material should be such that there is no resistance in copying the details. This usually depends on the flow properties of the impression material and the compression exerted by the gingival tissues.

Additional silicone impression materials have been used as impression material for 20 years they became extremely popular during the past decade. Although they are among the most expensive impression materials, they are now used widely in fixed prosthodontics, removable prosthodontics, operative dentistry and implant dentistry. The popularity of these materials is because of combination of excellent physical properties, handling characteristics and good dimensional stability and can be poured at the convenience of the operator and also allow the opportunity to make a second pour.

In the present study, the maximum experimental error (0.23 %) was 1 order of magnitude smaller than the calculated distortion of the impression and die. Therefore its effect on the accuracy of the data-collecting process can be ignored. It was also in the range of experimental errors found in previous related studies [1, 8–10].

**Table 1** Experimental error (mm)

|  |  | Mean | Range | Standard deviation | Coefficient of variance (%) |
|---|---|---|---|---|---|
| Impression | Width 1 | 19.939 | 19.88–20.00 | 0.045 | 0.23 |
|  | Width 2 | 19.711 | 19.64–19.77 | 0.045 | 0.23 |
| Die | Width 1 | 19.951 | 19.89–20.01 | 0.036 | 0.18 |
|  | Width 2 | 19.669 | 19.61–19.74 | 0.038 | 0.19 |

**Graph 1** Maximum mean distortion of impression and dies made from abutments with different sulcular widths (%)
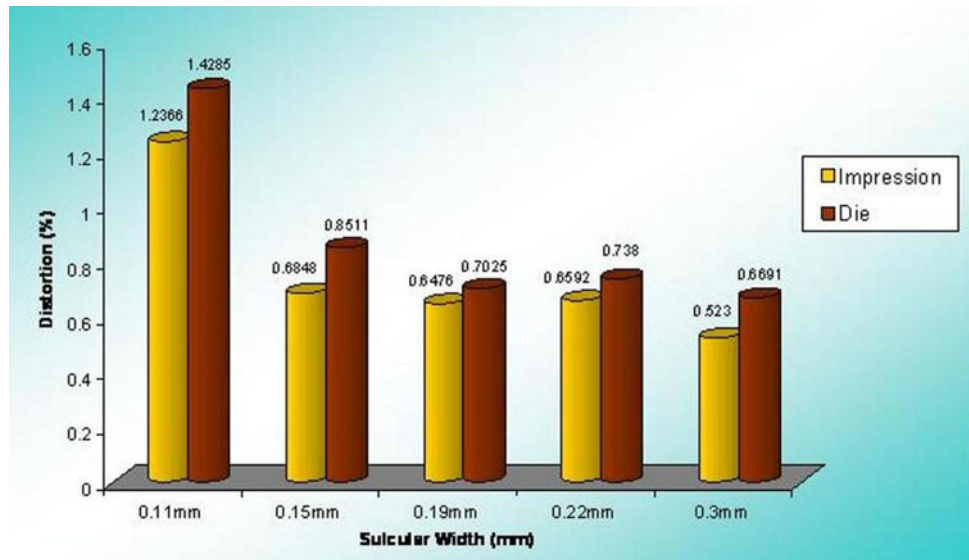


**Graph 2** CV of impression and dies made from abutments with different sulcular widths (%)
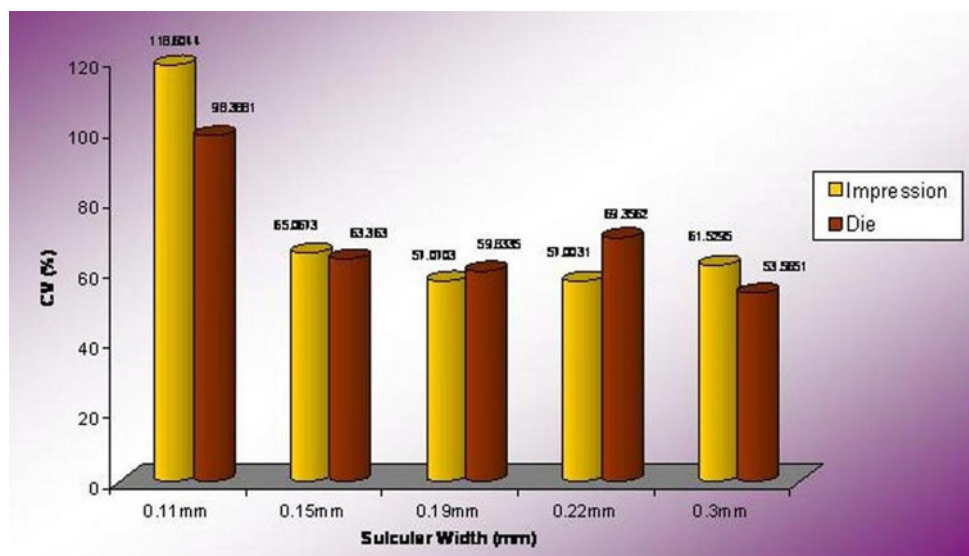


**Table 2** Summary of one-way ANOVA—impressions with varied sulcular widths

| Source of variance | Sum of squares | df | Mean square | $F$ test | $P$ value | $F$ |
|---|---|---|---|---|---|---|
| Between group | 11.05294 | 9 | 1.228104 | 3.160757 | 0.001405 | 1.929426 |
| Within group | 73.82403 | 190 | 0.388548 | | | |
| Total | 84.87696 | 199 | | | | |

**Table 3** Summary of one-way ANOVA—dies with varied sulcular widths

| Source of variance | Sum of squares | df | Mean square | $F$ test | $P$ value | $F$ |
|---|---|---|---|---|---|---|
| Between group | 12.22678 | 9 | 1.358531 | 3.493291 | 0.000509 | 1.929426 |
| Within group | 73.89045 | 190 | 0.388897 | | | |
| Total | 86.11723 | 199 | | | | |

A dimensional distortion of an impression in any one direction may render the die inaccurate and clinically unacceptable. In this study the largest mean dimensional distortion in any direction measured for each impression and die was selected to represent its inaccuracy.

Linear accuracy is affected by the dimensional change occurring during setting and by the permanent deformation caused by separation of the impression from the undercut and narrow spaces around the abutments. The smooth, parallel-sided metal abutment in a recess does not replicate

**Table 4** Number of impressions with defects for different sulcular widths

| Sulcular width of abutment (mm) | No of defects in impression (n = 20) |
| --- | --- |
| 0.11 | 15 |
| 0.15 | 3 |
| 0.19 | 3 |
| 0.22 | 4 |
| 0.3 | 0 |

the clinical situation of a tapered, prepared tooth surrounded by retracted gingiva with its elastic property and salivary moisture of oral environment. However the model serves for comparison of the distortion of the impression and die made at various sulcular widths.

In the present study, impressions with thin margin of 0.11 mm showed the maximum mean distortion of 1.24 % (Graph 1; Table 2) whereas other thicker margins of 0.15, 0.19, 0.22 and 0.3 mm showed a distortion of only 0.52–0.68 % (Graph 1; Table 2). Therefore thinnest extension of the impression material into the sulcus showed about two times greatest dimensional distortion when compared to the wider sulcular group.

This experiment examined the inaccuracies at the early stage of crown fabrication i.e. impression making and die fabrication. Further inaccuracies will be added in the consecutive processes of crown casting, electroforming [11] or milling [12], ceramic firing, etc. In the literature, there is no agreement on the clinically tolerable gap between the crown and tooth. It may vary between 0.31 and 1.19 mm [13]. Thus it may be concluded that distortion of 0.52–1.23 mm at this early stage has clinical significance.

The American Dental Association Council on Dental Materials and Devices specification no. 19 [14] stipulates a 2.5 % maximum permanent deformation for type I non-aqueous elastomeric dental impression material. This specification was determined by a compressive test using a 20 mm thick bulk of impression material in the present experiment. The distortion was of a tensile nature, occurring while separating the impression from the model and cannot be compared to specification no. 19.

To our knowledge, no other standard has been fixed for distortion of impression material during impression making, but Hondrum [15], took an arbitrary estimation of 0.4 % deformation to be the significant deformation limit. He did not try to define a precise point. But rather to compare the tested materials nevertheless judging by this estimate, the distortion at a sulcular width of 0.11 mm was significant.

Also when comparing impression of similar thickness (0.23–0.72 mm) Hansson and Eklund [16] showed a greater distortion (1.9–2 %) than that in the present study (0.52–0.68 %) which possibly resulted from the undercut

present in that study and it has been shown that impressions with greater thickness of materials have distortion of 0.1–0.6 % [8, 17, 18].

In the study of Hansson and Eklund [16] the CV for narrow spaces was much larger (130 %) than for wider spaces (32 %). The present study, using narrow space but without undercuts, showed similar trends for narrow sulci of 0.11 mm where the CV was 72–118 % while for wider sulci of 0.15, 0.19, 0.22 and 0.3 mm the CV was 52–68 % (Graph 2).

The large dimensional distortion and clinical variances in the 0.11 mm sulci width suggest that the impressions were not accurate. Since the clinician cannot distinguish between an accurate and a distorted impression, only sulcular widths giving consistently accurate impressions would be clinically acceptable. (Graphs 1, 2) show that 0.15 mm is the smallest sulcular width producing consistent impressions which coincides with the previous study [19]. Therefore it can be inferred that the method employed to achieve gingival retraction should provide a minimum retraction of 0.35 mm, 0.15 mm needed for the flow of impression material as per the results of present study and 0.20 mm of reversion of gingival sulcus once the cord is removed as reported by Laufer et al. [4].

Defect attributed to tear or to failure of the impression material to flow and completely fill the sulcus was found in narrow sulci of 0.11 mm. It is important that the impression should not rupture when being removed from the mouth. In the previous study impression remnants were found in the gingival crevices in 8 of 125 patients following silicone impression procedures [20]. The recovery of an impression without marginal tears depends on the thickness of the impression margin, the tear strength of the impression material, and its ability to undergo elastic deformation when being removed from undercut areas. The problem of the tearing of impression margins in narrow sulci may be overcome by using impression materials with high tear strength. However, these materials like the polysulfide impression material permanently deformed rather than tearing away and results in a complete but distorted impression.

## Conclusion

Considering the limitations of this study, the following conclusions can be drawn.

(1) It was not always possible to predictably obtain accurate impression in a sulcus of 0.11 mm or lesser

(2) Dimensionally accurate impressions were obtained in a sulcus of 0.15 mm and wider

(3) Defect free impressions were obtained when the sulcular width was 0.15 mm and wider

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