

# A Classification System to Measure the Implant-Abutment Microgap

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**Purpose:** A large microgap at the implant-abutment interface has been reported to result in adverse effects, including screw loosening, abutment rotation, and abutment fracture. However, a standardized classification of the implant-abutment interface has not been established. The purposes of this investigation were (1) to propose a classification system based on the horizontal and vertical microgap of the implant-abutment interface and (2) to compare the implant-abutment interface in 4 groups of abutments. **Materials and Methods:** Forty-eight randomly selected external hexagonal implants were paired with (1) machined titanium abutments, (2) premachined palladium abutments cast-on with palladium alloy, (3) plastic burnout abutments cast with nickel chromium alloy, and (4) plastic burnout abutments cast with cobalt chromium alloy. A comparison of the horizontal and vertical microgaps at the implant-abutment interface was completed at 8 locations on each specimen to the nearest micrometer using an optical microscope with a magnification of 150 $\times$ . Group means and significant differences between groups were determined by analysis of variance and Tukey multiple-comparisons post-hoc analysis.  $P < .05$  was the threshold for statistical significance. **Results:** There was no significant difference between groups with respect to vertical misfit. For horizontal misfit, machined titanium abutments presented significantly higher horizontal misfit compared to other groups ( $P < .001$ ). Premachined cast-on abutments had significantly higher horizontal misfit than cast NiCr abutments ( $P < .001$ ). In the proposed classification system, 23% of all sites measured at the implant-abutment interface had an ideal relationship, 34% had a horizontal discrepancy only, 4% had a vertical discrepancy only, and 39% had both vertical and horizontal discrepancies. **Conclusion:** The proposed implant-abutment classification system demonstrated a way to characterize and compare the microgap at the implant-abutment interface. INT J ORAL MAXILLOFAC IMPLANTS 2007;22:879-885

**Key words:** implant-abutment interface, microgap

The implant-abutment connection can be an area where adverse biologic and mechanical consequences occur. Biologic complications such as increased microleakage,<sup>1-3</sup> gingivitis,<sup>4</sup> and bone loss<sup>5,6</sup> have been reported to result from a poorly adapted implant-abutment interface. Mechanical complications, such as increased incidences of abut-

ment rotation and breakage,<sup>7,8</sup> screw loosening,<sup>9</sup> and preload reduction, have also been reported to occur with a poorly adapted implant-abutment interface.<sup>10</sup>

Bacterial microleakage and colonization have been documented to occur with a number of different types of implant-abutment connections.<sup>1</sup> Although the presence of inflammatory cells adjacent to a microgap has not been related to the presence of plaque,<sup>11</sup> peaks of inflammatory cells are reported to occur approximately .50 mm coronal to the microgap.<sup>4</sup> A microgap at the implant-abutment interface allows micro-organisms to proliferate close to the epithelial attachment, which often results in bone resorption approximately 2 mm apical to the microgap.<sup>5</sup>

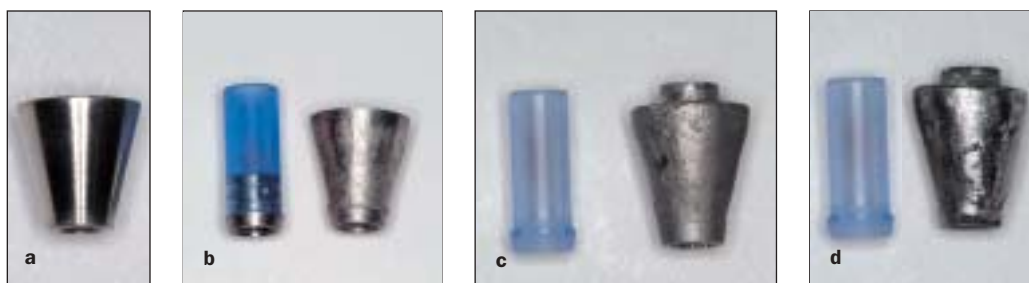
The mechanical complications of poor abutment fit can include screw loosening, abutment rotation, and abutment fracture.<sup>7-10,12</sup> Binon<sup>12</sup> showed that screw loosening was more likely when abutments were poorly adapted. Carr et al<sup>10</sup> showed that irregu-

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**Fig 1** Paired internal hexagon abutments: (a) machined titanium abutment, (b) premachined palladium abutment cast-on with palladium, (c) plastic burnout abutment cast with nickel chromium, and (d) plastic burnout abutment cast with cobalt chromium.

larities produced during casting procedures resulted in a 30% decrease in preload values, which was predicted to increase screw loosening. Kano et al<sup>13</sup> reported that casting procedures decrease the percentage of applied torque and that machined abutments retained significantly greater detorque values compared to cast abutments.

Although many studies have shown the importance of implant-abutment fit,<sup>5-10,14,15</sup> an agreed-upon standard for measuring the microgap has not been established.<sup>16,17</sup> This has made comparisons between studies difficult.<sup>14,18-24</sup> Many of the techniques established for measuring marginal fit of conventional restorations have been adapted and used for measuring the implant-abutment interface. They include the direct view, cross-sectional measurement after sectioning, the impression technique, and the use of an explorer with a visual examination.<sup>15,16,25,26</sup> The direct view is convenient and, since it is nondestructive, it may be used to monitor change over time. However, rounded margins often have no repeatable point of reference, which makes it difficult to determine margin overcontouring by direct viewing.<sup>26</sup> Therefore, specimens must be on the same focal plane and in a reproducible position.<sup>27</sup> The cross-sectional view allows greater accuracy in determining the measuring points than the direct view. However, the cross-sectional view requires specimens to be embedded and sectioned and therefore cannot be used in studies where measurements are required before and after an intervention. Most studies in which the implant-abutment interface has been recorded have not reported defined reference points.<sup>1,2,28</sup>

The use of profile projection by transmitted illumination on a microscope stage is a way to combine the positive aspects of both the direct view and cross-sectional techniques when measuring marginal gaps in an *in vitro* setting. With this technique an optical microscope can be used as a profilometer when the light under the microscope stage illuminates the outer surface of the interface and the internal gap. This procedure allows the use of a repeatable measuring point, so that specimens can be

measured before and after an intervention. The optical microscope is an easy instrument to use and operate at a low cost; it can be used for laboratory and clinical studies as well as by technicians.

Although many investigators have used marginal fit as an outcome measurement, a standardized classification for the implant-abutment interface has not been established. A standardized classification system to characterize the implant-abutment interface would facilitate comparisons between studies and could help improve understanding of complications related to the implant-abutment interface. The purpose of this study was 2-fold: (1) to propose a classification system that systematically details the horizontal and vertical microgap of the implant-abutment interface and (2) to compare the implant-abutment interface in 4 groups of machined and premachined cast-on and plastic-cast abutments.

## MATERIALS AND METHODS

Forty-eight randomly selected external hexagonal implants, with a 3.75-mm platform, (Conexão Master; Conexão Sistema de Prótese, São Paulo, Brazil) and 48 external hex compatible abutments (Conexão Master External Hex Abutments, Conexão Sistema de Prótese) were placed in 4 groups of 12 specimens, according to the type of abutment: (1) machined titanium abutments (machined), (2) premachined cast-on palladium abutments having a metal base and a plastic sleeve cast-on with palladium alloy (premachined cast-on), (3) plastic burnout abutments cast with nickel chromium alloy (NiCr cast abutments) and (4) plastic burnout abutments cast with cobalt chromium alloy (CoCr cast abutments; Fig 1).

For group 1, titanium abutments were directly obtained from the manufacturer in a conical shape 8 mm high and 8 mm wide at their widest point. Because the machined titanium abutments were not subjected to any type of casting procedure, they were used as a control.

**Table 1 Casting Alloy Composition (%) and Melting Interval (°C)**

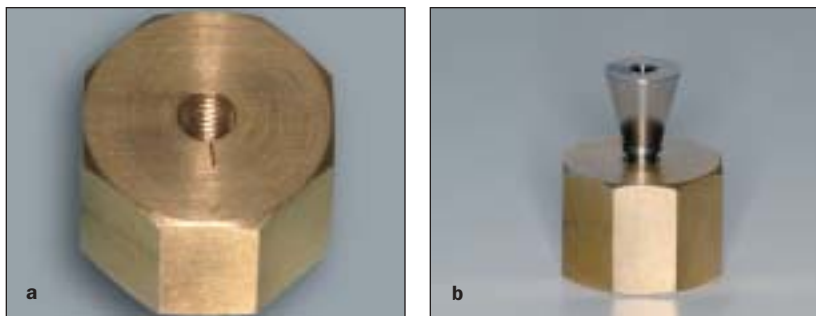
Group	Alloy	Pd	Ag	Co	Cr	Ni	Melting interval
2	Pors-on 4*	57.8	30				1175 to 1275
3	VeraBond2†				12.5	77.05	1200 to 1315
4	CoCr Mold Alloy*			63	28		1320 to 1380

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**Fig 2a** Holding device used to position implant-abutment interface for microscopic analysis. Internal threads allowed the implant to be screwed into position.

**Fig 2b** Octagonal shape allowed the sample to be uniformly rotated and measured in 8 equally spaced locations. Index points in the holding device and abutment were used to orient specimens in same position for each measurement.



For groups 2, 3, and 4, premachined palladium cast-on abutments and plastic burnout abutments were waxed to the same basic shape as the machined titanium abutments from group 1. The waxed abutments were attached to an implant, inserted into a lathe spindle, and refined to the same shape as the control group with a wax cutting blade. After waxing and shaping, the internal hexagonal abutment recess was carefully cleaned with alcohol. The wax patterns were individually invested with phosphate bonded investment (Termocast, São Paulo, SP, Brazil) and cast with the selected alloy (Table 1) following the manufacturer's directions using conventional lost-wax casting technique. After casting, samples were allowed to bench cool. Divesting was carefully performed using glass beads (80  $\mu\text{m}$ ) at 1 bar pressure, followed by ultrasonic cleaning. No further polishing and finishing were performed. Prior to measurements of misfit, samples from each group were selected randomly, and the hexagonal recess was viewed under a scanning electron microscope and photographed.

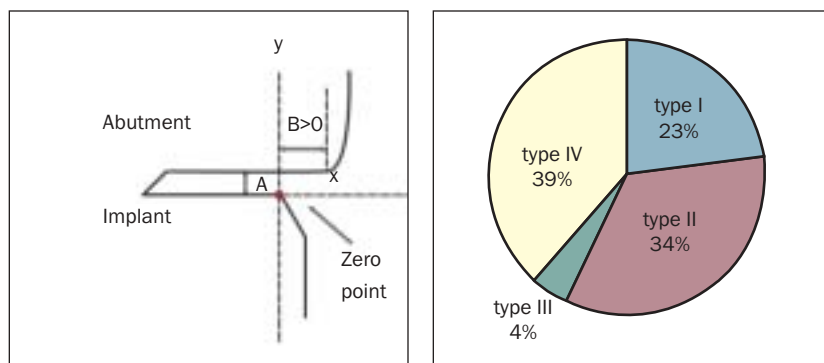
A holding device was designed and fabricated to position the implant-abutment interface for microscopic analysis (Figs 2a and 2b). The holding device had an octagonal external shape and internal threads, which allowed the implant to be screwed into position. The octagonal shape allowed the sample to be uniformly rotated and measured in 8 equally spaced locations using a protocol similar to the technique described by Sorensen.<sup>26</sup> Each of the 8

locations was measured 3 times to determine a mean value for that location. Index points in the holding device and the abutment were used to orient the specimens for each measurement.<sup>29</sup>

An optical microscope (Toolmaker Microscope; Gaertner Scientific, Chicago, IL) with a magnification of 150 $\times$  and a measuring grid providing precision to 1  $\mu\text{m}$  (Measuring Equipment; Gaertner Scientific) was used for measurement of the implant-abutment microgap. Using the eyepiece cross-hair reticule as a reference, the sample was positioned so that the X line passed through the horizontal platform of the implant and the vertical Y line crossed the X line at the most external point of the horizontal platform of the implant. The intersection between X and Y lines defined the point (X = 0, Y = 0) from which the horizontal and vertical misfit was measured for all specimens.

The vertical misfit (A) was defined as the vertical gap measured from the zero point on a line through the most external point of the implant (not considering the rounding of the outer contour of the implant) and the same area of the abutment (Fig 3). The horizontal misfit (B) was defined as the horizontal gap from the zero point to the external contour of the abutment. If the abutment was wider than the implant, there was a horizontal overcontour (B > 0); if the abutment was narrower in diameter than the implant, there was an undercontour (B < 0).

The proposed classification for the implant-abutment interface includes both horizontal and vertical components:



**Fig 3 (left)** Reference points for measurement of the implant-abutment interface. The zero point was defined as the intersection of the x and y axes. Horizontal misfit was defined in relation to the x axis, and vertical misfit was defined by the y axis.

**Fig 4 (right)** Misfit classification: Overall results.

- Type I: No horizontal or vertical gap could be measured ( $A = 0$  and  $B = 0$ ). This class was considered ideal.
- Type II: Only horizontal misfit was observed; the abutment was either undercontoured ( $B < 0$ ) or overcontoured ( $B > 0$ ).
- Type III: Only vertical misfit ( $A > 0$ ) was observed.
- Type IV: Both horizontal and vertical misfit were observed.

Horizontal and vertical gaps were analyzed according to the proposed classification at 8 locations on each implant-abutment assembly. Vertical and horizontal gap measurements were completed in 8 locations on each of 12 specimens, resulting in a total of 96 measurements for each group. Specimens were prepared and positioned for measurements at the microscope by a single investigator, who was also responsible for recording data. A second investigator, who was unaware of the group designation of the specimen being measured, analyzed each specimen under the microscope. Means and standard deviation were calculated for the vertical and horizontal misfit in each of the 4 groups. One-way analysis of variance (ANOVA) was used to test for differences, and the Tukey multiple-comparisons post-hoc analysis was performed. Results were considered significant if  $P$  was less than .05.

## RESULTS

When all specimens were analyzed according to the proposed classification (Fig 4), 23% of all sites measured at the implant-abutment interface had an ideal relationship (Fig 4). Individual results for each group are presented in Fig 5. The overall mean horizontal microgap measured at the implant-abutment interface was significantly greater than the overall vertical microgap ( $41.2 \pm 15.5 \mu\text{m}$  versus  $7.9 \pm 6.9 \mu\text{m}$ ; Table 2).

In the machined group (group 1), none of the measured sites had an ideal interface; 65% had a hor-

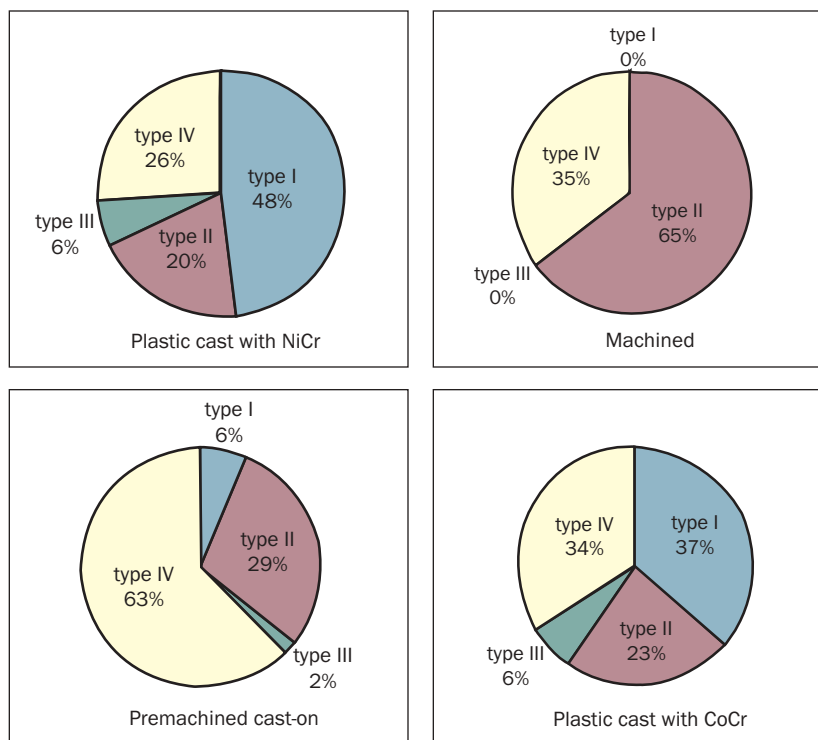
izontal discrepancy only (type II), no measured sites had vertical discrepancies only (type III), and 35% had both horizontal and vertical discrepancies (type IV; Fig 5). For the machined titanium abutments, the average horizontal misfit was  $89.1 \pm 14.1 \mu\text{m}$ , and the vertical misfit was  $5.6 \pm 6.4 \mu\text{m}$  (Table 2).

In the premachined cast-on group (group 2), 6% of all measured sites had an ideal implant-abutment interface (type I), 29% had a horizontal discrepancy only (type II), 2% had a vertical discrepancy only (type III), and 63% had both a horizontal and vertical discrepancy (type IV; Fig 5). The average horizontal misfit was  $39.2 \pm 16.9 \mu\text{m}$ ; the average vertical misfit was  $11.1 \pm 8.2 \mu\text{m}$  (Table 2).

In group 3, 48% of all measured sites had an ideal implant-abutment interface (type I), 20% had a horizontal discrepancy only (type II), 6% had a vertical discrepancy only (type III), and 26% had both a horizontal and vertical discrepancy (type IV; Fig 5). In this group, the average horizontal misfit was  $13.5 \pm 9.5 \mu\text{m}$ , and the average vertical misfit was  $8.0 \pm 9.3 \mu\text{m}$  (Table 2).

In group 4, 37% of all measured sites had an ideal implant-abutment interface (type I), 23% had a horizontal discrepancy only (type II), 6% had a vertical discrepancy only (type III), and 34% had both a horizontal and vertical discrepancy (type IV; Fig 5). In this group, the average horizontal misfit was  $23.0 \pm 21.4 \mu\text{m}$ , and the average vertical misfit was  $7.0 \pm 3.8 \mu\text{m}$  (Table 2).

Horizontal misfit was seen alone or in combination with vertical misfit (Table 3). Among machined titanium abutments, 65% of specimens had horizontal undercontour and 35% had both horizontal undercontour and vertical misfit (type IV). Among premachined cast-on abutments, 74.0% of the specimens were undercontoured and 17.7% were overcontoured. Among plastic burnout abutments cast with NiCr, 31.2% of the specimens were undercontoured and 14.6% were overcontoured. For plastic burnout abutments cast with CoCr, 51.1% of the specimens were undercontoured and 6.2% were overcontoured.

**Fig 5** Misfit classification by abutment group.**Table 2** Mean Values and Standard Deviations for Horizontal and Vertical Misfit ( $\mu\text{m}$ )

Group	Horizontal misfit	Vertical misfit
Machined	89.1 $\pm$ 14.1	5.6 $\pm$ 6.4
Premachined cast-on	39.2 $\pm$ 16.9	11.1 $\pm$ 8.2
Plastic burnout abutments cast with NiCr	13.5 $\pm$ 9.5	8.0 $\pm$ 9.3
Plastic burnout abutments cast with CoCr	23.0 $\pm$ 21.4	7.0 $\pm$ 3.8
Average	41.2 $\pm$ 15.5	7.9 $\pm$ 6.9

**Table 3** Undercontour and Overcontour Horizontal Misfit (%)

	Type II Horizontal misfit		Type IV Horizontal and vertical misfit	
	Undercontour	Overcontour	Undercontour	Overcontour
Machined	64.6	0	35.4	0
Premachined cast-on	16.7	12.5	57.3	5.2
Plastic burnout abutments cast with NiCr	10.4	9.4	20.8	5.2
Plastic burnout abutments cast with CoCr	21.9	1.0	29.2	5.2
Average	28.4	5.7	35.7	3.9

The most common type of misfit was a combination of type IV misfit (39%), followed by type II (34%). No significant differences were found between groups with respect to vertical misfit. Machined titanium abutments presented significantly higher horizontal misfit compared to the other groups ( $P < .001$ ). Premachined cast-on abutments had significantly higher horizontal misfit than plastic burnout abutments cast with NiCr ( $P < .001$ ).

## DISCUSSION

Classification systems have been used in implant dentistry to better characterize clinical findings and more accurately compare studies as well as products. For example, the bone quality classification proposed by Lekholm and Zarb<sup>30</sup> has been helpful to better understand implant failures in bone of varying quality. The classification system proposed for the implant-abut-

ment interface outlines a method for comparing the microgap in a systematic way. Although many studies have shown that the implant-abutment marginal fit is important,<sup>9,10</sup> comparisons between studies have often been difficult because different measuring methods have been used.<sup>4–6,9,10,14,15,18–24</sup>

The ideal clinical finding would be no horizontal or vertical gaps (type I). In this study, an ideal fit was seen in only 23% of all specimens. Ideal fit was not seen with machined titanium abutments and was seen with only a low percentage (6%) of premachined cast-on abutments. However, an ideal marginal relationship was seen in 48% of plastic burnout abutments cast with NiCr and 37% of plastic burnout abutments cast with CoCr. These findings are inconsistent with results reported by Byrne et al,<sup>8</sup> who reported poor marginal fit with the use of plastic burnout components.

In the present study, the mean horizontal misfit was 89.1  $\mu\text{m}$  in the machined group. This is consistent with the findings of Byrne et al<sup>8</sup> who determined that machined titanium abutments had an average horizontal misfit of 66  $\mu\text{m}$  and found most abutments to have a horizontal undercontour. In the present study, 100% of the abutments in the machined titanium group were undercontoured. As can be seen from Table 2, the premachined and cast abutments were also much more likely to be undercontoured than overcontoured. Designing components with a negative horizontal misfit, or abutment undercontour, is essentially a design feature to facilitate abutment placement.<sup>8</sup>

The high standard deviation observed for mean horizontal misfit in the present study (14.1  $\mu\text{m}$  for machined titanium abutments and 16.9  $\mu\text{m}$  for premachined cast-on abutments) was consistent with the findings of Byrne et al<sup>8</sup> (66  $\pm$  20  $\mu\text{m}$  for machined titanium abutments and 11  $\pm$  15  $\mu\text{m}$  for premachined cast-on gold abutments). The high standard deviation found in both studies may be due to the variability inherent in casting procedures as well as the machining tolerances of manufacturers.

In the present study, the most common type of misfit was type IV misfit. The combination of horizontal and vertical misfit may result in less stability due to rocking of components.<sup>31</sup> Also, the combination of horizontal and vertical misfit may result in a larger area for the accumulation of bacteria and plaque than other misfit types. Discrepancies offer an environment for de novo plaque formation and/or plaque retention that is difficult to clean.<sup>3</sup> In the present study, machined titanium abutments had the smallest vertical microgap of the 4 groups (5.6  $\mu\text{m}$ ). This finding is in agreement with other investigations in which vertical gaps of less than 10  $\mu\text{m}$  were

found for manufactured components.<sup>1,2,10,15</sup> Guindy et al<sup>2</sup> found an average of 4  $\mu\text{m}$  of vertical misfit for machined titanium abutments, while Jansen et al<sup>1</sup> found 10  $\mu\text{m}$  of vertical misfit for machined titanium abutments.

The present results indicate that there was no significant difference among the 4 groups with respect to vertical misfit, which is in contrast to a previous study that determined a higher vertical discrepancy for cast abutments than for premachined cast-on abutments.<sup>8</sup> The difference in results between the findings and Byrne et al<sup>8</sup> could be related to differences in the designs of the components studied, manufacturers' tolerances, or casting and finishing differences, which have been shown to affect fit.<sup>10</sup> Future investigations that include comparisons of plastic burnout components from different manufacturers using a standardized casting and measuring technique will likely provide better information about the variables influencing the microgap.

## CONCLUSION

Within the limitations of this in vitro study, it was found that horizontal misfit was greater than vertical misfit in all groups, including the machined group. The classification system for categorizing the implant-abutment interface would allow more systematic comparison between studies.

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