



# FRACTURE RESISTANCE OF SOFT TISSUE LEVEL IMPLANTS AFTER CYCLIC LOADING AND EXTERNAL MODIFICATION

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**Statement of problem.** The exposure of the implant collar in the esthetic zone is a challenging complication of implant dentistry. The preparation of the exposed implant collar to create room for restorative material may decrease the strength of the abutment/implant assembly.

**Purpose.** The purpose of this in vitro study was to evaluate the effect on the failure load of preparing a 0.5-mm chamfer finish line on an implant collar at various apical depths.

**Material and methods.** Thirty solid abutments and 30 implants were screwed into a customized metal mold at a 30-degree angle to the vertical axis. An intact group (IN) (control) (n=10) had no preparation, experimental group P1 had a 0.5-mm chamfer margin placed 1 mm apical to the implant/abutment interface, and experimental group P2 had the margin placed 2 mm apical. The specimens were subjected to a fatigue loading of 200 N for 1 000 000 cycles. Unfractured specimens were then loaded until failure. Mean fracture load (MFL) values were compared with 1-way ANOVA, and the Tukey test was used to identify differences among groups ( $\alpha=.05$ ).

**Results.** One specimen from both the IN and P1 groups and 2 specimens from the P2 group failed after fatigue loading. Significant differences in the MFL values were found between the IN group (3825) and P1 group (2944),  $P<.001$  and between the IN group and the P2 group (2553),  $P<.001$ .

**Conclusions.** The mean load required to fracture the abutment/implant assembly decreased significantly after various amounts of implant collar preparation. (J Prosthet Dent 2013;109:30-36)

## CLINICAL IMPLICATIONS

The effect of reducing the exposed implant collar to create room for restorative material was investigated. Although mean fracture loads were significantly reduced after preparation (0.5 mm) of the implant collar 1 and 2 mm apical to the abutment/implant interface, they exceeded the maximum occlusal forces reported previously.

Gingival recession associated with a dental implant is a complication that may lead to supragingival exposure of the implant body.<sup>1,2</sup> This is unacceptable in esthetically critical areas and may be addressed by either surgical

or prosthodontic intervention. Several surgical techniques of hard and/or soft tissue grafting have been reported in an attempt to cover the exposed implant body,<sup>3,4</sup> but their success in covering an exposed implant

is dependent on many factors beyond the control of the operator. Bacterial contamination of the exposed implant is one, and several chemical and mechanical methods of decontaminating the implant surface have

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been reported.<sup>3,5-8</sup> Another factor is a thin periimplant biotype, which lessens the chances of surgical success. The risk of aggravating the situation should be presented to the patient before surgery as part of the informed consent procedure.

The use of either a direct or indirect restoration to cover the exposed implant body may necessitate preparation of the implant. The preparation of the implant body allows for a proper emergence profile and contour and provides a path of insertion for a complete veneer crown or retainer. The direct preparation of an abutment/implant assembly for various other reasons has also been reported in the literature.<sup>5,6,8,9</sup> Such preparation of the exposed implant may not only involve the removal of bulk material but also lead to the introduction of surface flaws on the prepared surfaces. Both the removal of material and the introduction of surface flaws may weaken the abutment/implant assembly, but little or no information is available to show whether this occurs.

The purpose of this study was to compare the effect of fatigue load cycling on the fracture load of an intact abutment/implant assembly (control group). Two experimental groups of the same abutment/implant complexes, which had been minimally but incrementally altered by external preparation of the implant body with a diamond rotary cutting instrument, were formed. The study was designed to test the null hypothesis that there is no difference between the postfatigue mean fracture load (MFL) values of the control and experimental groups.

## MATERIAL AND METHODS

Power analysis for a 1-way ANOVA design was used to determine the specimen size ( $N=30$ , corresponding to 92% power,  $P<.05$  and 0.7071 effect size). Thirty implants and abutments were divided into 3 equal groups. An intact group (IN) ( $n=10$ ) had no preparation, a second group (P1) had a 0.5-mm chamfer margin 1 mm apical to

the implant/abutment interface, and a third group (P2) had a 0.5-mm chamfer margin 2 mm apical to the same interface.

Inlay casting wax (Green Inlay Casting Wax; Kerr Corp, Orange, Calif) was used to pattern a custom square mold, in which an implant body (Standard Implant, 4.8 mm x 12 mm; Straumann USA LLC, Andover, Mass) was inserted at an angle of 30 degrees to the vertical axis. The interface between the smooth collar and rough airborne large particle abraded/acid etched (SLA) surface

was even with the top surface of the wax pattern.

The wax pattern was invested with gypsum-bonded investment material (Cristobolite; Whip Mix Corp., Louisville, Ky) and cast in base metal alloy (Ni-Cr; 2% beryllium) (Rexillum III; Jeneric Pentron, Wallingford, Conn) to fabricate a custom square metal mold. The metal mold was airborne-particle abraded with 50  $\mu$ m alumina to remove the investment material and to maintain the integrity of the threads (Fig. 1).

Solid 4-mm length abutments



**1** Integrity of implant threads formed by implant when metal mold was fabricated. Integrity was needed to allow screwing and unscrewing of tested implants.



**2** Preparation of facial aspect of implant collar until 0.5 mm deep chamfer finish line obtained.



**3** Failed specimen after fatigue loading due to presence of space between abutment and implant.



**4** Failed specimen after application of vertical compressive load.

(Straumann USA LLC) were screwed into the implants, and each assembly was screwed into the metal mold to the manufacturer's recommended torque of 35 Ncm with a torque driver (Straumann USA LLC). The metal mold was mounted on the table of a milling device with a putty type condensation silicone impression material (Virtual; Ivoclar Vivadent, Amherst, NY), and a high speed handpiece was mounted to the movable arm of the milling device (Muss MF30 Milling Machine; Muss Dental GmbH, Wennigsen, Germany) with photopolymerizing acrylic resin (Triad; Dentsply Trubyte, York, Pa).

All preparations were made by a single operator using a 4-degree taper, coarse diamond chamfer rotary instrument. One-half of the implant circumference, representing the facial aspect of the implant, was prepared until a 0.5-mm deep chamfer finish line was obtained (Fig. 2). The finish line on the direct facial surface was blended mesially and distally with the unprepared implant surface. Group IN was not prepared and served as a control group. Group P1 had 0.5-mm facial finish lines 1 mm apical to the abutment/implant interface, and Group P2 had 0.5 mm finish lines 2

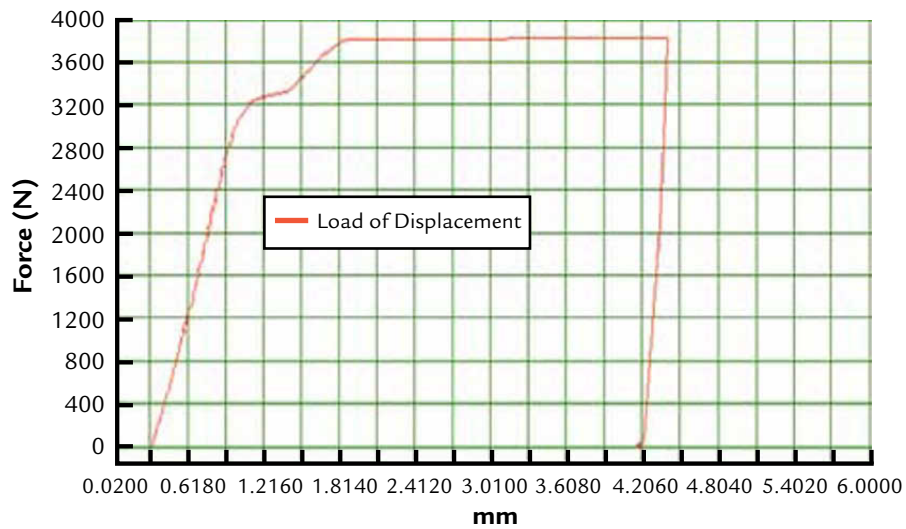
mm apical to the interface.

The metal mold was then placed horizontally in a universal mechanical testing system (MTS 810; MTS Corp, Eden Prairie, Minn), resulting in a 60 degree off-axis implant assembly tilt to simulate the position of a maxillary central incisor. The MTS machine used in this study was calibrated by the manufacturer immediately before the start of the experiment.

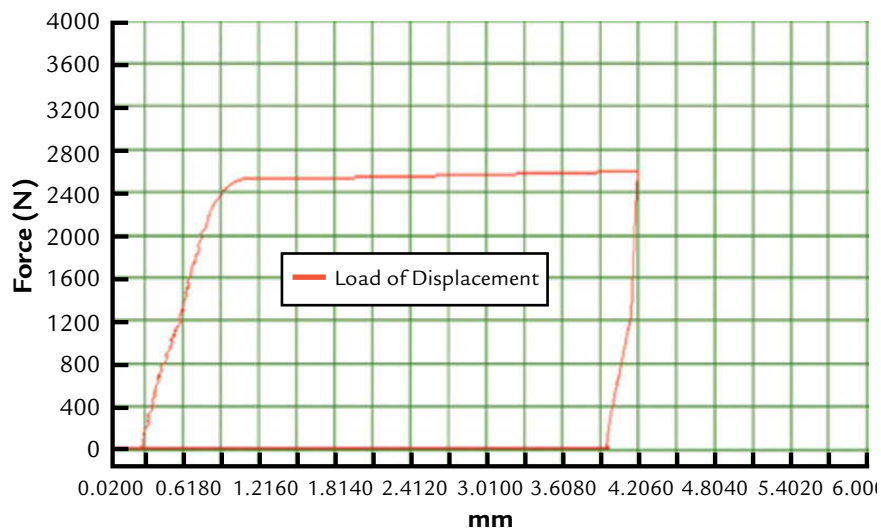
Compressive sinusoidal fatigue load cycles (minimum load, 10 N; maximum load, 210 N; mean level, 110 N) were applied on the implant/abutment assembly for 1 000 000 cycles at 10 Hz on the incisal edge to simulate 40 months of service in the human mouth.<sup>10-13</sup>

The specimens were examined under a light microscope (40x; Celestron, Cincinnati, Ohio) after fatigue loading. The presence of a space between the implant and the abutment indicated the failure of the specimen (Fig. 3). The MTS 810 machine then applied vertical compressive loads on the incisal edge of each abutment with a crosshead speed of 0.1 mm/minute until failure (Fig. 4). The MTS machine was connected to a personal computer (Dell, Round Rock, Texas) with a data acquisition card (PCIM-DAS16JR/1; Measurement Computing, Norton, Mass) and software (DAYSLab; Measurement Computing) to plot the load-displacement profile (Figs. 5-7). The maximum load registered by the data acquisition card was used as the final load before fracture (hereafter designated simply as fracture load) for statistical analysis. Testing was performed in no special order within each group or between the groups.

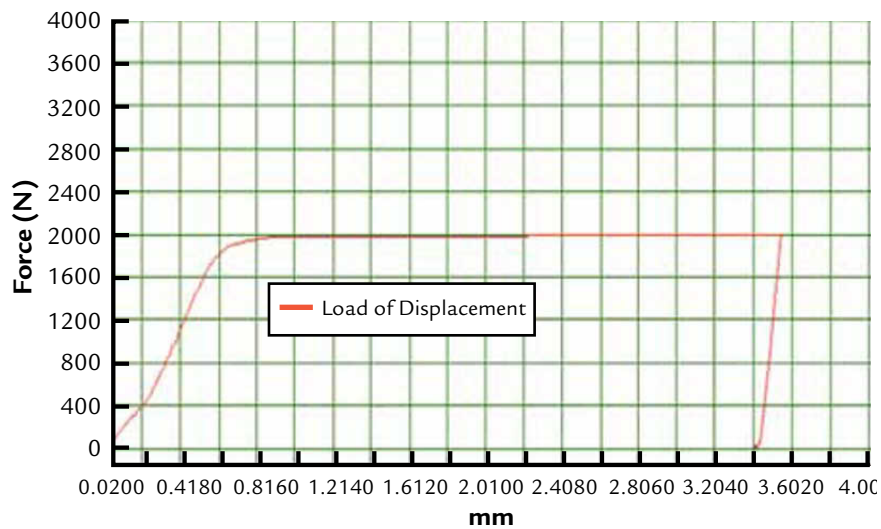
Statistical software (SPSS Statistical Software for Windows v15; IBM Corp, Chicago, Ill) was used to evaluate the MFL data. A 1-way ANOVA ( $\alpha=.05$ ) was used to compare the MFL data of the 3 groups. The post hoc Tukey pairwise contrast was performed to identify statistically significant differences ( $P<.05$ ) between the means of individual groups.



**5** Load-displacement profile, specimen from group IN (control).



**6** Load-displacement profile, specimen from group P1.



**7** Load-displacement profile, specimen from group P2.



**TABLE I.** Pairwise multiple comparisons of MFL values with Tukey Post Hoc Test

		Mean	SD	P
IN	P1	880.667 <sup>a</sup>	224.637	.002
	P2	1272.056 <sup>a</sup>	231.551	<.001
P1	IN	-880.667 <sup>a</sup>	224.637	.002
	P2	391.389	231.551	.230
P2	IN	-1272.056 <sup>a</sup>	231.551	<.001
	P1	-391.389	231.551	.230

<sup>a</sup>The mean difference is significant at  $P<.05$ .

RESULTS

After fatigue loading, the specimens were examined under the light microscope. Microscopic evaluation revealed that 1 specimen from the IN and P1 groups and 2 specimens from the P2 group had failed.

The MFL values (N) and SDs ranged from 3825 (524) for the IN group to 2944 (288) for the P1 and 2553 (580) for the P2. The distribution of fracture loads was examined and was found to follow an approximately normal distribution. The mean of the fracture loads appears to decrease as greater amounts of material are removed with the rotary instrument, showing a detectable tendency to weaken the abutment-implant assembly.

One-way ANOVA indicated that the MFL values among the fatigued groups differ significantly ( $P<.001$ ). A summary of the post hoc Tukey test results (Table I), however, shows that statistically significant ( $P<.01$ ) differences were observed between the control IN and both experimental groups P1 and P2 but not between experimental groups P1 and P2 ( $P>.05$ ). Nevertheless, the mean values appear to indicate that limited preparation of the implant marginally weakens the abutment-implant assembly.

DISCUSSION

A statistically significant difference in the mean fracture loads be-

tween the control and experimental groups was found. Therefore, the null hypothesis was rejected. Those fracture loads should be viewed in a clinical context. It has been shown that the bone supporting dental implants may resorb over time.<sup>14</sup> As a result, periimplant soft tissue may recede with the bone. As the growing number of implant patients age, the potential exists for an increasing number of patients with exposed implant bodies. Therefore, patient treatments that were initially an esthetic success may become an esthetic failure over time. Several options are available to the practitioner to correct this. One of those options would be to mechanically reduce the exposed implant body in preparation for coverage with an esthetically suitable restorative material. However, by doing so, the strength of the resulting assembly will, to some degree, be reduced. An average occlusal force of 120 N in an axial direction on a single molar implant restoration has been reported.<sup>15</sup> Another study reported an occlusal force in an axial direction on implants of up to 847 N for men and 595 N for women.<sup>16</sup>

The current study evaluated the load required to fracture the implant/abutment assembly after limited mechanical preparation and cyclic fatigue loading. The load required to fracture the implant/abutment assembly after cyclic fatigue loading and mechanical preparation was significantly greater than the maximum occlusal force generated intraorally.

These findings are in agreement with an in vitro study of the extreme lateral loading of a 1-piece abutment connected to an internal conical design implant<sup>17</sup> but were well above the forces reported in other studies.<sup>18,19</sup>

There may be several reasons the fracture loads observed in the current study are higher than those in other studies. Mollersten et al<sup>19</sup> applied the load perpendicular to the long axis of the specimens. In that study, the authors proposed that if the load were more axial to the long axis of the specimens, the MFL values would be greater. Such is the case in the current study, as the load was applied at 60 degrees off axis to simulate clinical settings.

Another reason for the higher fracture loads observed may be the mechanical properties of the implant system used in this study. The implant material in this study was grade 4 CP Ti, which exhibits high mechanical properties.<sup>20</sup> Additionally, the abutment/implant interface of the implant system used in this study incorporates several design elements which have been found to maximize its resistance to force. One is the correlation that has been found between the depth of the abutment/implant interface and MFL values. Systems with deeper interfaces resist larger bending forces than those with shallow interfaces.<sup>17-19</sup> Another is when the abutment and its retaining screw are made as a single component (as in this study) rather than 2 individual components, it is able to resist higher forces.<sup>17-19</sup> Thirdly, an internal friction-fit conical abutment/implant interface design is mechanically more stable than a slip-fit external design.<sup>17,18,21</sup> In the external connection design, the abutment screw is primarily responsible for maintaining the stability of the implant/abutment assembly under functional load.<sup>22</sup> By contrast, the internal conical design mainly resists nonaxial loading by means of the tapered configuration of the implant joint. This interface design uses frictional forces to maintain intimate contact between the abutment and implant and pre-

vents the abutment from being displaced.<sup>21,23</sup> A final explanation may be that the diameter of the implants used in this study was larger than that used in previous studies.<sup>17-19,23</sup>

Preparation of the implant collar reduced the fracture load in groups P1 and P2. ANOVA revealed significant fracture load variations among groups IN, P1, and P2. Preparation of the implants may not only cause thinning of the implant, but also introduce flaws on the prepared surfaces. Both of these may be responsible for the weakening of the implant-abutment assembly during the postfatigue fracture tests. Since the effect of fatigue is well known to be sensitive to the presence and propagation of flaws under cyclic loading, the MFL values of different groups without fatigue loading were also tested. The results showed a detectable decrease in MFL values but no statistically significant differences ( $P>.05$ ) among group MFL values. This would suggest that the propagation of surface flaws and the bulk reduction during implant preparation may interact to weaken the implants. This is also consistent with the observation that failure occurred with fracture of the collar wall and the head of the screw just below the base of the cone in the abutment (Fig. 8). The failure mode of the screw was similar to that which occurred in the Norton study,<sup>18</sup> and both smaller screw diameters and the machining of flaws in the screws may influence the MFL values. Minimum displacement within the implant/abutment interface was observed. Displacement patterns were asymmetrical on the load-displacement profile, particularly when the material reached the plastic deformation stage. This could be explained by the differences in the thickness of the collar wall among the groups due to the preparation of the implant collar.

Even after a million fatigue loading cycles, the load required to cause fracture of the abutment screw and the wall of the implant was large and well beyond any load that can be gen-



**8** Fracture of collar wall and head of screw just below base of cone in abutment.

erated intraorally. The conclusion is that the minimal preparation regimen examined in this study could be a viable procedure for implant-supported prostheses, a conclusion supported by a clinical study in which no incidence of abutment screw fracture was reported.<sup>24</sup>

A limitation of this study may be that complete crowns were not cemented on the implant/abutment assembly. The study's primary focus was the MFL required to fracture the implant/abutment assembly. A previous study found that fracture occurred between the crowns and the abutments under relatively low force.<sup>19</sup>

In this study, it should be noted that only 1 implant system was examined, which provides a more focused study design with easily interpretable data. Implant systems vary in the materials used for implant components, depth of abutment/implant interface, friction versus slip-fit abutment/implant interface, abutment screw design, and implant diameter. The variations of implant size among different implant systems may compromise the comparison. Most manufacturers have narrow, regular, and wide diameter implants. The narrow diameter implant in one system is not the same narrow diameter as in another implant system. Mollersten et al<sup>19</sup> reported in their study that if implant diameter had been considered, the outcome of the comparison might have been different.

## CONCLUSION

Within the limitations of this study, the following conclusions were drawn:

1. Mean fracture loads required to fracture the abutment/implant assembly decreased significantly after various amounts of the implant collar preparation.
2. Loads required to fracture a prepared abutment/implant assembly were significantly higher than the maximum occlusal force that has been reported in previous studies.
3. Minimal preparation of a Straumann implant collar of 0.5 mm in depth and 1 or 2 mm below the abutment/implant interface may be a viable option for managing an exposed implant collar.

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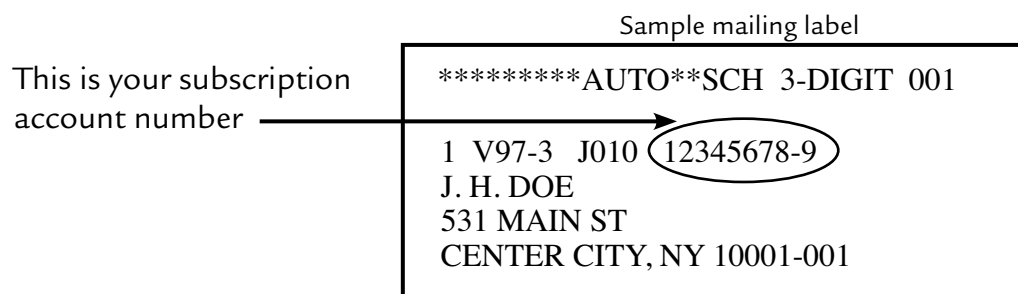
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