Stability of Implant-Abutment Connection After Using the Rescue Kit: An In Vitro Study

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Purpose: To evaluate whether removing a fractured abutment screw with a specific rescue device negatively affects the success of a new restoration in terms of early abutment loosening. Materials and Methods: Implants (n = 10) with a regular platform of 4.1 mm (tissue level [TL]) and implants (n = 10) with a reduced diameter of 3.3 mm (bone level [BL]) were used. The screws of eight respective abutments for both implant types were artificially weakened in order to fracture during torque application for abutment insertion. The fractured abutment screws were removed applying a specific rescue kit. The implant inner threads were cleaned and remodeled with a system-specific tapper. New abutments were inserted, and computer-aided design/computer-aided manufactured (CAD/CAM) full zirconia crowns were luted. Aging by thermal cycling and mechanical loading was performed with a customized masticator simulator, and the number of crown and/or abutment loosenings was determined. In cases in which no loosening was observed, sawing and grinding were performed to determine the contact zone between the inner implant thread and abutment screw. Data were compared with a control group, eg, unmodified implant-abutment connections. Results: No abutment loosening was observed. All crowns were in function after mastication simulation. The inner thread contact zones of both test groups were generally smaller than in the control group, with a mean contact area of 448.6 μm and 459 μm for BL implants, and 608.8 μm and 620.5 μm for the TL implants in test and control groups, respectively. Conclusion: Removing a fractured abutment screw with a specific rescue device and modifying the inner thread seems not to negatively affect the functional connection between a new abutment and the implant. Int J Oral Maxillofac Implants 2018;33:1274–1278. doi: 10.11607/jomi.6386

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Implants have shown survival rates above 90% up to 8 years and may be regarded as a standard therapy for replacing teeth.¹ However, biologic and technical complications may occur, impairing the general implant’s success. One technical complication is related to occlusal overload and a consecutive fracture of the abutment screw. Of all technical complications that might occur, abutment screw fracture was detected with an incidence of < 1% up to 8%.²⁻⁴ The rate of both abutment and screw fracture after 10 years is estimated to be 4.1%.⁵ This low incidence may be explained by the precise fit of the connections between abutments and implants and the abutment screw connections to the inner implant threads. If abutment screw fracture occurs, high forces and/or parafunctional load is necessary.⁶ Before fracture of an abutment screw, a cold welding between the fractured abutment screw and the inner implant thread may occur due to the high forces and friction. Removing fractured abutment screws that are cold welded is clinically very challenging and in some cases even impossible.⁷ This situation is very unpleasant since a biologically healthy implant cannot be used clinically. To replace the tooth, explanation followed by a new implantation may be taken into consideration. This, however, is associated with high morbidity, unknown prognosis, and high costs. Therefore, several techniques—such as rotating with a

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sound application of ultrasound, creating a slot in the fractured screw, and application of counterclockwise rotation—with small burs are described in the literature to remove a fractured abutment screw.\textsuperscript{8,9} According to the authors’ experiences, these techniques can be successfully used in situations in which the abutment screw was loose and that is the reason for its fracture under load, but not in cases in which cold welding occurs. In these cases, specific rescue instruments are necessary to remove the fractured abutment screw. Some implant brands have developed individual rescue kits, which allow performing a guided counterclockwise drilling through the implant in order to loosen and remove the fractured screw.\textsuperscript{10} Specific rescue kits (Rescue Kit TL and Rescue Kit BL, Institut Straumann) use the inner implant space on top of the fractured abutment screw to reproducibly fix a specific metal guiding tube. With a rescue drill, it is possible to apply loosening torque on the fractured screw in a guided way by drilling counterclockwise into the fractured screw. Despite using the guidance tool, it seems impossible to avoid small deviations in the axis during drilling. Though the drill has a smaller diameter than the body of the abutment screw, damage of the inner implant thread might occur. Accordingly, it is recommended by the manufacturer to use a specific tapper in order to reshape the original inner thread and additionally remove bore chips, which could impede the insertion of a new abutment screw due to wedging. The tapping, however, is associated with a loss of material, eg, reduction of the shape of the inner implant thread. Regarding the rescue of fractured abutment screws using the rescue kit, the question is raised as to whether the tapping and reshaping of the inner thread might negatively affect the connection between an original new abutment screw and the implant. Due to a reduced contact between the abutment screw and the inner implant thread, loosening of abutments under function might occur earlier and with a higher frequency than in original implant-abutment connections. Until now, no study has evaluated the influence of rescuing a fractured screw on the mechanical stability of a newly inserted original abutment. The aim of the present study was to evaluate whether rescuing a fractured screw using the rescue kit negatively affects the mechanical stability of a newly inserted abutment under function. The hypothesis was that the connection between the abutment and implant loosens earlier when compared with an original connection under standardized loading conditions in a mastication simulator.

MATERIALS AND METHODS

Ten tissue-level (TL) implants (Tissue Level Roxolid, RN 4.1 mm 10 SP, Institut Straumann) and 10 bone-level (BL) implants (Bone Level Roxolid, NC 3.3 mm 10 SP, Institut Straumann) were each divided into two groups: test group (n = 8) and control group (n = 2). For the test groups, the screws of the abutments were weakened with a cut-off wheel (Fig 1). To standardize this procedure, weakening was performed under a light microscope with a magnification of \( \times 8 \). Every abutment screw was sawed halfway through. This protocol was chosen according to a pilot project (not published data) that shows that abutment screws sawed halfway through fractured with an insertion torque of approximately 35 Ncm (\( \pm 5 \) Ncm). For the TL implants, standard abutments were used (RN Solid Abutment 6°, 5.5; Institut Straumann), and for the BL implants, abutments with a reduced diameter (NC Cem Abutment, D3.5 GH2, AH4, Institut Straumann) were used. The weakened abutments were mounted on the implants and tightened until the screw of the abutment fractured (Fig 2). Then, the respective rescue kits were used to remove the fractured screw from the implant according to the manufacturer’s recommendations (Fig 3). Therefore, a tube for guidance was inserted into the implant. A specific drill was then inserted into the tube and turned counterclockwise in order to loosen the fractured abutment screw. After removing the
screws, the inner threads were rinsed with saline solution. Additionally, a specific taper of the rescue kit was used with Vaseline in order to shape the threads and to remove the bore chips. The shaping was gently repeated several times until the inner core of the implants seemed to be cleaned of all chips and the taper could easily be turned in both directions without friction.

For the control groups (n = 2 implants per group), standard unaltered implants were used (no weakening or fracturing of any abutment).

New original abutments as described above were put on all the implants and tightened with 35 Ncm, applying a torque control ratchet. One minute after the first tightening, torque control was repeated.

Computer-aided design/computer-assisted manufactured (CAD/CAM) zirconia crowns (Cercon, DeguDent, Densply Sirona) were produced and adhesively luted on the abutments with dual core adhesive cement (Panavia F 2.0, Kuraray America). Then, the implants were embedded into resin blocks and mounted into a thermal cycling machine. A loading force of 50 N was applied on the crowns in a 35-degree angle to the central axis. Thermal cycling (TC) and mechanical loading (ML) (TC: 3 × 6,000 cycles between 5°C and 55°C, distilled water, 2 minutes each cycle; ML: 50 N for 3.6 × 10⁶ cycles; f = 1.6 Hz; mouth opening, 2 mm) with online failure control were performed to simulate and control fatigue failures according to a validated protocol¹¹ (Fig 4). In order to simulate clinical anterior loadings, the angle between the long axis of the implant and the horizontal plane was set to 135 degrees, corresponding to the mean interincisal angle.¹² Steatite balls (d = 12 mm, CeramTec) were used as antagonists. They were positioned in maximal contact at the palatal surface 2 mm from the incisal edges of the crowns.

The first outcome measure was the number of abutment or crown loosenings. All implants in which no loosening occurred were additionally cut parallel to the long axis into two pieces (Exakt STD 30 Diamond Band Saw, Exakt Apparatebau) in order to estimate the rescue kit’s effect on the contact between the inner tap’s inner thread and abutment screw, and to compare this with the contact of unmodified threads in the control group. Therefore, the implants with crowns were completely embedded into resin. The implants were cut in the middle of the long axis into two pieces according to the sawing and grinding technique described by Donath and Breuner.¹³ To determine the contact zone between the abutment screw and inner implant thread, digital images of each implant half’s inner thread were taken with a microscope (Binokular Stereomikroskop 6x-32x M7A, Wild/Leica, Leica Microsystems; Auflichtmikroskop Leica DMRM 50x ×1000x, Leica Microsystems), and the images were uploaded into software (Leica Application Suite V 4.0 2011, Leica Microsystems). This allowed manual drawing of a line along the shape of the inner threads and automatic calculation (in µm) of the resulting contact (Figs 5 and 6) (Leica IM 500 VS R222 Analyse software, Leica Microsystems).

A descriptive statistic was performed with SPSS (IBM SPSS Statistics 20; IBM) comparing the control and test groups for TL and BL implants.

RESULTS

In both groups for TL and BL implants, no abutment or crown loosening occurred. All crowns and abutments survived the thermal cycling and mechanical loading independently of the shape of the modified inner thread.

All implants were sawed and grinded in order to measure the contact zone between the implant’s inner thread and the abutment screw. Due to technical complications (fracture of the saw blade, extra axial sawing, and incomplete grinding), 8, 3, 10, and 2 implant contact zones could be evaluated in the experimental TL group, the control TL group, the experimental BL group, and the control BL group, respectively. The control group for both implant types showed higher mean contact zone values than the experimental groups (Table 1) as a result of the manipulation of the inner thread. Differences between experimental and control groups were small for both implant types.

DISCUSSION

The present study shows that the rescuing of fractured abutment screws and the re-shaping of the thread according to the manufacturer’s recommendations has no negative influence on the loosening of abutments.

Fig 4 Setup of the TCML performance with a customized masticator simulator.
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and crowns when compared with original implant-abutment connections under in vitro TCML conditions. The results were surprising, as the authors were expecting a premature abutment loosening of the implants with modified inner threads. The modification of the inner thread is associated with a reduced contact between the abutment and the implant. This leads to diminished mechanical strength and might result in early abutment loosening. In order to evaluate the loss of contact between the abutment screw and inner thread related to the tapping after removing the fractured screw, each implant was cut into two pieces in order to determine the contact zone between the abutment screw and implant inner thread. The small difference in measured contact area between the experimental and control groups for both implant types could explain why no abutment loosening occurred during mechanical and thermal stress tests. Obviously, the modified threads still had enough contact to the abutment screw to successfully anchor the original abutment with sufficient strength. The mean contact of the experimental BL implants was 448.6 µm, compared with an original BL implant, where a mean length of contact of 459 µm was determined. The higher values for the TL implant with 608.8 µm for the experimental and 620.5 µm for the control implant are related to the bigger diameter of the TL implants used and the different design of the inner threads of both implant types. The authors attempted to determine contact zones between the inner threads of the implants and the threads of the abutments, but some of the abutments loosened during sawing and grinding procedures, thus making it impossible to determine the contact zones between the inner implant thread and the abutment screw. Instead, only the inner implant contact areas were determined and compared to the inner threads of untreated implants. However, the data have some flaws that need to be taken into consideration: First, the sample size of two control implants is rather small, and it is debatable if calculating a mean value is reasonable; second, a high number of separated implants in the TL and BL experimental groups could not be included in the measurements due to complications during implant preparation, such as improper axis or fractures of the saw blade. With regard to these complications, the measured surfaces can only be interpreted as a tendency. Unfortunately, there are no data in the literature that could serve as a reference to compare the results, and therefore, the authors were not able to perform a power calculation.

Table 1  Measured Contact Zones Between Inner Threads and New Abutment Screw After Retapping (in µm)

<table>
<thead>
<tr>
<th>Thread total length of contact (µm)</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>BL experimental</td>
<td>395.0</td>
<td>502.0</td>
<td>448.6</td>
<td>39.6</td>
</tr>
<tr>
<td>BL control</td>
<td>405.0</td>
<td>514.0</td>
<td>459.0</td>
<td>54.5</td>
</tr>
<tr>
<td>TL experimental</td>
<td>519.0</td>
<td>694.0</td>
<td>608.8</td>
<td>64.4</td>
</tr>
<tr>
<td>TL control</td>
<td>517.0</td>
<td>724.0</td>
<td>620.5</td>
<td>146.4</td>
</tr>
</tbody>
</table>

BL = bone level; TL = tissue level.

Fig 5  Measurement of the contact zone by drawing a line (original, untreated TL implant).

Fig 6  Measurement of the inner thread by drawing a line along the shape (test group TL implant).

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However, in many studies in which simulators are used, the number of tested implants is eight, and the authors therefore decided to use this already-proved protocol. Nevertheless, the main focus of this study was to evaluate whether using the rescue kit to remove a fractured abutment screw and tapping a new inner thread might influence the survival of a new crown-abutment insert in terms of early loss under load. Abutment screw fracture under clinical conditions is rather uncommon, and a clinical setup is ethically not justifiable. Therefore, it was decided to perform an in vitro study using mechanical and thermal stress mimicking clinical conditions. The specific study design and machine gave the opportunity to imitate a load and stress of approximately 5 years in vivo. However, though using machines to simulate clinical stress represents a reliable and reproducible study design, the present setup has one big weakness compared with clinical conditions: In order to fracture the abutment screws, they were weakened by a cutting wheel manually before inserting the abutment. Using a torque control key, approximately 35 Ncm (± 5 Ncm) was applied on the torque instrument, which is the clinically recommended value for tightening abutments on implants. Though the screw-weakening process was standardized, the presented procedure to weaken and break an abutment screw still could not be identical for each single implant. This might have influenced the fit of the fractured abutment screw, subsequently influencing the difficulty in removing the fractured screw part. However, compared with clinical situations, a cold welding could not be imitated, so it can be assumed that under clinical conditions the rescuing might be much more difficult. This, however, was obvious during the in vitro setup when compared with the clinical experiences of the authors. A more complicated screw removal of a cold welded fracture screw is directly associated with a more-important damage of the inner thread, which might negatively affect the new connection.

CONCLUSIONS

Within the limitations of this in vitro study, it seems that rescuing a fractured abutment screw is justified and associated with a promising prognosis concerning the success and long-term stability of a new abutment and crown insertion.

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REFERENCES