Failure mode of implant-abutment connections after horizontal cyclic loading

**Language:** English

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**Introduction**

The use of single tooth implant restorations in the lateral region is increasing. The clinical long term success of those restorations seems to be less dependent on a failure of the osseointegration, but rather more on the material fatigue of the implant’s components.

![Single tooth implant](image1)

In-vivo implant fracture with cycle loading caused fatigue striations

**Objectives**

The purpose of this study was to evaluate the mode of failure, as well as the reasons of failure resulting from constructional and manufacture weaknesses, after cyclic loading in a chewing simulator.

**Material und Methods**

For this experiment a chewing simulator (Fa. Willytec) was modified as follows in order to:

- a.) lead the horizontal cyclic load, which was exercised bilaterally (±100N, at a 8mm distance), on the implant-abutment connection.
- b.) measure the maximum of dynamical chewing force in each chewing cycle
- c.) to detect and register during the cyclic loading the interfering signal (coming out from a piezoelectric sound-sensor), which precedes any micro-movement/loosening, and to stop the chewing simulator at the time of detection.
The implant abutment connection was:

- a.) mounted with the suggested screw torque and
- b.) standardized V2A caps (Ø 5mm) were cemented on the abutments
- c.) embedded with "Knethartz, Metaflux" in accordance with DIN 148

<table>
<thead>
<tr>
<th>Force</th>
<th>Frequency</th>
<th>cycle loadings</th>
<th>loading weight</th>
<th>distance</th>
<th>speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>± 100</td>
<td>2</td>
<td>1.000,00000</td>
<td>5</td>
<td>± 1.5</td>
<td>40</td>
</tr>
</tbody>
</table>

Experimental Parameters of the chewing simulator

Results

<table>
<thead>
<tr>
<th>Implantat</th>
<th>diameter [Implant/Abutment]</th>
<th>average life [cycles]</th>
<th>failure rate [number]</th>
<th>failure mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITI-Synoktamilling cylinder</td>
<td>4.8 / 3.45</td>
<td>149.758</td>
<td>8</td>
<td>8 micromovements / 8 loosenings</td>
</tr>
<tr>
<td>ITI-WN-massive abutment</td>
<td>4.8 / 3.45</td>
<td>395.699</td>
<td>8</td>
<td>6 screw- / 2 abutment fractures</td>
</tr>
<tr>
<td>Impla</td>
<td>4.2 / 4.2</td>
<td>524.714</td>
<td>6</td>
<td>6 screw fractures</td>
</tr>
<tr>
<td>Brånemark</td>
<td>4.0 / 4.0</td>
<td>599.495</td>
<td>8</td>
<td>8 screw- / 5 implant fractures</td>
</tr>
<tr>
<td>Camlog</td>
<td>4.3 / 4.3</td>
<td>822.656</td>
<td>3</td>
<td>1 loosening / 2 screw fractures</td>
</tr>
<tr>
<td>Frialit 2</td>
<td>4.5 / 4.5</td>
<td>968.813</td>
<td>1</td>
<td>1 screw- / 1 abutment fracture</td>
</tr>
<tr>
<td>Bio-Horizon</td>
<td>5.0 / 5.0</td>
<td>1.000.000</td>
<td>0</td>
<td>no failure to detected</td>
</tr>
<tr>
<td>Ankyllos</td>
<td>4.5 / 2.5</td>
<td>1.000.000</td>
<td>0</td>
<td>no failure to detected</td>
</tr>
</tbody>
</table>

Failure modes

Brånemark

- Implant fracture
- Implant shoulder
- Abutment
- Goldscrew fracture without plastic deformation
Embrittlement at fracture surface of the gold screw

Cycle loading caused fatigue striations at fracture surface of the Implant

ITI-SynOkta milling cylinder

Signal in course of time of a loosened ITI suprastructure

Frequency spektrum of a loosening ITI Suprastructure

\[ F = 0N \quad F = 100N \]

Dumping of suprastructure

Virgin connection

ITI-WN-massive Abutment

Screw fracture

Caused by incongruent conical surface = Flaw. ⇒ Abutment fracture
Implant Screw fracture

Caused by undersized Screw

5 of 6 fracured screws are easy to remove

At 1 of 6 fractures second fracture at the beginning of thread

Camlog Fracture of both Screws
Connection after 1.000.000 cycles

F = 0N
F = 50N
Dumping of abutment

Screw cracked
caused by loosening

Frialt 2
Fracture of connection:

Failed abutment is difficult to remove
Failed abutment is difficult to remove
Cycle loading caused fatigue striations

Ankylos
Before cyclic loadings

Congruent conical surface
After 1,000,000 cyclic loadings

Bio-Horizons

Caused of Implant diameter (5mm) no failure detected

**Discussion and Conclusions**

<table>
<thead>
<tr>
<th>Rate of failure (%)</th>
<th>NONE conical connections</th>
<th>conical connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>4.0</td>
<td>4.2</td>
</tr>
<tr>
<td>100</td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The material fatigue after horizontal cyclic loading depends on the intrinsic tolerance of the materials and the type of the connection between implant body and abutment. Force fit and form fit conical connections or none conical connections with a diameter up to 5mm, proved to have the minimal failure rate.

**Abbreviations**

- Implant-abutment connections (IAV)
- Loosening (L)
- Fractures (F)
- Micro movements (MM)

**This poster was submitted by Dipl.-Ing. Holger Zipprich.**

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**Material and Method**

- For the experiment a chewing simulator (Feining) was modified as follows in order to a) limit the horizontal cyclic load, which was exerted constantly at 30N, as three times the implant-abutment connection; b) minimize the forces acting on the implant-abutment connection to 0.6N, which is the amount of force during chewing, and c) simulate the chewing mechanism of the lips of the test subject.
- The implant-abutment connection was a) manufactured with the specified outer torque and b) measured with a specific instrument and compared to the values obtained in the experiments with the chewing simulator.
- Experimental parameters of the chewing simulator:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load</td>
<td>30N</td>
</tr>
<tr>
<td>Torque</td>
<td>0.6N</td>
</tr>
<tr>
<td>Frequency</td>
<td>2 Hz</td>
</tr>
</tbody>
</table>

**Results**

<table>
<thead>
<tr>
<th>Implant/ Abutment</th>
<th>Diameter (mm)</th>
<th>Average Load (N)</th>
<th>Failure Rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>4.5</td>
<td>400,000</td>
<td>0</td>
</tr>
<tr>
<td>B</td>
<td>4.5</td>
<td>300,000</td>
<td>0</td>
</tr>
<tr>
<td>C</td>
<td>4.5</td>
<td>200,000</td>
<td>0</td>
</tr>
</tbody>
</table>

**Summary**

The material fatigue after horizontal cyclic loading depends on the intrinsic tolerance of the materials and the type of the connection between implant body and abutment. Force fit and form fit conical connections or none conical connections with a diameter up to 5mm, proved to have the minimal failure rate.