Introduction

Inserting and tightening implantological components is not always easy, especially not in the posterior region. Starting in the early days of modern oral implantology, various ratchet techniques have become established to facilitate the insertion of implants and secondary structures at appropriate torque levels [1]. Today, the various implant systems use ratchets for inserting the implant and for tightening secondary elements such as retaining screws, healing abutments or other components [2, 3].

Clinicians evaluate the ratchets used for implant insertion based on their haptic experience and on subjective criteria for implant stability within the respective bony implant bed. For a more objective assessment of the torque applied, it is recommended to utilize controlled-torque ratchets to determine and document the effective torque during implant insertion and to assess whether the torque is sufficient for immediate loading or immediate restoration [4, 5]. In the event of excessive torque, clinicians then have the option to interrupt the implant insertion procedure and return to preparing the implant bed, to safely prevent unphysiological compression of the bone bed by excessive torque [6].

During the prosthetic phase, the ratchet allows the clinician to apply a uniform torque when connecting abutments to implants. Torque control helps avoid excessive torque that might result in thread failure [7]. Torque control also ensures that abutments are connected appropriately, creating a sufficient level of pre-tension for functional loads on the prosthetic components [8].

It is therefore important that the ratchets operate with reproducible precision to eliminate, to the largest extent possible, errors and complications both during the surgical and during the prosthetic phase.

As a part of the activities of the Qualification and Registration Committee – Scientific Research of the BDIZ EDI, several commercial manual ratchets for inserting screw implants and for attaching abutments were examined.

Accuracy of Manual Torque-limiting Devices for Use in Oral Implantology

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Fig. 1 Ratchet with 14 Ncm bit for hex screws (Dentsply Friadent, Mannheim).

Fig. 2 Ratchets for 20 and 30 Ncm with screwdriver bits (Zimmer, Freiburg).
Materials and methods

A number of implant manufacturers was selected based on their market penetration at the time of the study to obtain a set of torque ratchets to be examined for the accuracy of the torque delivered.

Different torque ratchet designs are available on the market today. Most ratchets are based either on a spring mechanism or on a deformable elastic metal component.

Internal spring ratchet systems may use individual torque bits with encased springs for different torque levels, or the adjustable spring of a single instrument can be set for various torque levels within a defined range. Ratchet systems with torque bits are characterized by a ratchet mechanism that is actuated at the pre-loaded torque, causing the ratchet to disengage (Figs. 1 and 2). One manufacturer offers an angled handpiece where the micromotor is replaced by a ratchet spring cassette to facilitate the application of a specific torque (Fig. 3).

Coil spring ratchets feature a bending mechanism that indicates when the set torque is reached. These systems are often very similar in design but differ in their capacity to accommodate standardized or system-specific bits (Figs. 4 and 5). Ratchet systems with spring rods transfer the torque directly from the ratchet handle to the screw, and the torque can be controlled via the corresponding elastic rod with markings on the measuring post that indicates the torque applied (Figs. 6 and 7).
The ratchets examined for the present study were classified as either internal-spring ratchets, coil spring ratchets or spring rod ratchets, as shown in Table 1. Obviously, internal spring ratchets require a separate instrument or at least a separate bit for each set torque level. The range of available torque levels varies depending on manufacturer and ratchet type. Torque levels of between 10 and 75 Ncm were evaluated. However, the ratchets are mainly used at torque levels of between 10 and 45 Ncm.

The AFTI measuring device (Halmtec, Switzerland) with a MT-Th 50 manual torque sensor was used for the measurements in this study. Its measuring sensor is based on deformation measurements via strain gauges. The standard accuracy class of the device is 0.5 percent of the maximum scale value for torque levels of 5 Ncm and above.

Each manual ratchet was fitted with a matching chuck for the prosthetic instrument used to ensure direct application of the torque, similar to what is happening during implantological treatment.

Because neither the patient nor the clinician is in a fixed position during the procedure, no workbench was used, unlike in the case of purely mechanical technical testing. Rather, the operator held the measuring device in one hand and a ratchet in the other. In this way, the accuracy of the maximum torque actually applied for a given set torque level was documented. To obtain statistically reproducible results, each torque was measured 30 times for each ratchet, compensating for the individual variance caused by the free experimental set-up by increasing the number of samples.

Statistical evaluation was performed for the total of all values obtained and by classified evaluation comparing measurements by clinically relevant torque ranges and design principles. As not all units could be set to the same selection of values, the relative deviation was calculated as a percentage of the respective set value. The range of variation of the data was illustrated by Tukey box plots, while dependencies were examined using univariate ANOVA and the Bonferroni post-hoc test.

### Table 1: Evaluated set torques for the various manufacturers and design principles.

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Internal spring</th>
<th>Coil spring</th>
<th>Spring rod</th>
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</thead>
<tbody>
<tr>
<td>Biomet 3i, Karlsruhe, DE (Cat B)</td>
<td>10, 20, 32 Ncm</td>
<td></td>
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<tr>
<td>Biomet 3i, Karlsruhe, DE (rti)</td>
<td>10 Ncm</td>
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<tr>
<td>bredent Medical, Senden, DE</td>
<td>10, 20, 30 Ncm</td>
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<tr>
<td>Camlog, Wimsheim, DE</td>
<td>10, 20, 30 Ncm</td>
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<tr>
<td>Dentsply Friadent, Mannheim, DE</td>
<td>14, 24 Ncm</td>
<td></td>
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<tr>
<td>Hader, La Chaux-de-Fonds, CH</td>
<td>20, 35, 45, (75) Ncm</td>
<td></td>
<td></td>
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<tr>
<td>Medentis, Dernau, DE</td>
<td>10, 20, 30 Ncm</td>
<td></td>
<td></td>
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<tr>
<td>Nobel Biocare, Cologne, DE</td>
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<td>15, 35 Ncm</td>
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<tr>
<td>Straumann, Freiburg, DE</td>
<td></td>
<td>15, 35 Ncm</td>
<td></td>
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<tr>
<td>Thommen, Weil am Rhein, DE</td>
<td></td>
<td>10, 15, 20, 25, 30, 35 Ncm</td>
<td></td>
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<tr>
<td>Z-Systems, Konstanz, DE</td>
<td></td>
<td>15, 20, 25, 30, 35 Ncm</td>
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<tr>
<td>Zimmer, Freiburg, DE</td>
<td>20, 30 Ncm</td>
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</tbody>
</table>
Results

A total of 12 different ratchet systems from 11 manufacturers with a range of selectable torque levels between 10 and 45 Ncm were examined. All in all, 1080 torque measurements were made. The evaluation of the absolute deviations measured in Ncm across all manufacturers and ratchet types shows only minor deviations with a median of -0.3 Ncm relative to the set value. The greatest positive deviation was 8.2 Ncm, while the greatest negative deviation was 8.4 Ncm. Calculated as a percentage, the median deviation was -1.5% of the set value. The greatest positive deviation was 82.5%, while the greatest negative deviation was 46%. It should be noted, however, that the upper limit of the 95% interquartile range showed a minimum of only 1.83% and a maximum of only -0.39%. The maximums should therefore be considered rarely occurring extremes. To improve the clarity of the following box plot illustrations, one extreme value and two outliers that deviated by 50% were excluded.

To specify the deviations, measurements were assigned to one of three classes. Due to the set torque values of the Zimmer ratchet with 20 and 30 Ncm, this data were assigned in the group 10–15 Ncm for the 20 Ncm and 20–30 Ncm for the 30 Ncm ratchet. In the 10–15 Ncm range, a median negative deviation of -0.26 Ncm or -1.9% was found. In the 20–32 Ncm range, the median deviation was 0.18 Ncm or -0.7%. In the 35–45 Ncm range, the median deviation was 1.0 Ncm or -2.7% (Figs. 8 and 9). The univariate ANOVA thus yielded a highly significant difference in absolute torque accuracy for the 35–45 Ncm range compared to the other two groups (p=0.000). When the deviation was calculated as a percentage, significant differences were found only between the 20–32 Ncm and the 35–45 Ncm ranges, while all other combinations exhibited no significant differences.

Comparison of instrument designs yielded median deviations for internal spring ratchets of -0.9 Ncm or -4.5%, compared to coil spring ratchets at -0.3 Ncm or -1.5% and spring rod ratchets at -0.1 Ncm or -0.5% (Fig. 10). The univariate ANOVA did not show any significant differences for absolute measurements between the various instrument designs. When the deviation was calculated as a percentage, significant differences were found only between the spring rod and internal spring designs.

Comparison between the systems across all measurements shows only minor variations with median ranging from -7.8% to 1.2% (Fig. 11). Looking at the measurements for the systems as classified by torque ranges, the medians show greater variations ranging from -5.3% to 14.1% (Fig. 12).
Discussion

The present study shows that the variations for each system are relatively small overall, staying close to the set values. A previously published study on the accuracy of the torque control of electrically/electronically controlled surgical units showed considerable variation with significant differences in the torques applied as a function of the set values for the respective systems [10]. Actual values tend to fall short of, rather than exceed, the set values.

The deviation from the set value in percent is relevant to the relative risk of applying an inadequate torque for the respective torque range. Despite the large number of measurements (n = 1080), there were only three cases of relative deviations exceeding 50% of the set value. This indicates that the ratchets available on the market today have become much more reliable than those in previous studies, where deviations of 165% were found [11]. When it comes to everyday clinical application, it should be noted that deviations of up to more than 80%, although rare, may still occur.

However, looking at the group values for measurements in the 10–15 Ncm range, greater quartile values are found than for the 20–32 Ncm and 35–75 Ncm ranges. This is particularly evident when comparing different systems, where the relative variation is particularly large in the lower Ncm ranges for the respective systems.

A comparison of the different design principles has shown that, when tabulating all measurements, the only significant relative difference was found for the spring rod system compared to the internal spring system and that they were no significant differences for the absolute measurements. Hence, none of the three designs offers any significant advantage in terms of torque accuracy.

Summary

Although the variations in absolute terms are higher in the upper torque ranges, variations relative to the respective set torque in percent show only small variations. It should be noted, however, that certain applications may result in relatively high deviations, meaning that verification may be indicated in certain situations. The accuracy of the torque-limiting functions offers clinicians a high-level safety because it gives them a reliable indication of the clinical consequences of the torque applied.

A list of references will be supplied by the editorial office on request.

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