# Microelectronic wear-time documentation of removable orthodontic devices detects heterogeneous wear behavior and individualizes treatment planning

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**Introduction:** The aim of this study was to investigate whether microelectronic wear-time documentation can contribute to individualized orthodontic management. **Methods:** The wear times and behaviors of 281 patients undergoing orthodontic treatment with removable appliances were quantified and analyzed using the TheraMon microelectronic system (Sales Agency Gschladt, Hargelsberg, Austria) over a 6-month treatment period. **Results:** The 281 study participants wore their removable appliances for a median of 9.0 hours per day, compared with the 12 to 15 hours per day prescribed. Wear behavior was variable and heterogeneous in patients with almost identical median wear times, with fluctuating and numerous zero wear-time periods observed. **Conclusions:** Both the duration of daily wear time and the wear behavior need to be considered to individualize the prescription for wear time; this is made possible with microelectronic wear-time documentation. Individual prescription changes based on the wear-time documentation can be arranged with patients in a shared decision-making process to achieve effective and successful treatment progress. (Am J Orthod Dentofacial Orthop 2014;146:155-60)

Indication-dependent removable appliances, fixed appliances, and combinations of both are used in orthodontic treatment. In Europe, the less expensive and less invasive removable appliances are commonly used for orthodontic treatment, mainly in the first phase of 2-phase active treatment but also during the retention phase.[1-3] In the United States, fixed multibracket appliances are largely preferred for the active phase. Removable devices, such as the Hawley retainer (used by 58% of American orthodontists), are used first in the subsequent retention phase.[4,5]

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The success of orthodontic treatment with removable devices depends on regular wearing of the device at the prescribed times, often for years. This high expectation of adherence to the wear-time prescription has been a major argument against the use of removable devices, since it is often not achieved. Until recently, the practitioner has only been able to prescribe empirically derived, and usually standardized, wear times, the choice of which can largely depend on personal preference, experience, or bias. In addition, it is unclear which wear-time protocols apply optimal pressure with respect to tooth movement.

It has been shown that appliance wear times can be reliably documented over a period of months using a newly developed, temperature-sensitive microsensor (TheraMon microelectronic system; Sales Agency Gschladt, Hargelsberg, Austria) incorporated into removable appliances by polymerization.[6,7] The wear times are determined at 15-minute intervals based on the temperature of the oral cavity and are displayed as a wear-time graph. The wear-time graph can be accessed at any time during treatment, and the instant retrieval of data means that the information is on hand at checkup appointments.

Wear-time documentation not only is accepted by most patients but is also well received, as shown in a recent questionnaire study.[8] Furthermore, when the patient is made aware of wear-time data, this has a positive effect on adherence.[9] Microelectronic wear-time documentation can therefore be used with confidence in the clinic; in our experience, it is being requested by more patients and their parents. Effective treatment depends on efficient transfer of the intermittent forces generated by removable appliances to the dentoalveolar complex. Therefore, both median wear-time duration and daily wear behavior might be expected to have a significant effect on treatment outcome. Here we analyze, for the first time, how wear time becomes individualized by measuring individual execution of prescribed wear times using microelectronically quantified wear-time data.

## MATERIAL AND METHODS

The commercially available TheraMon microsensor was used to measure wear times of removable appliances (plates and functional orthodontic devices) in each patient during the active treatment phase. The sensor was incorporated into the appliance by polymerization according to published methods.[10] The recorded wear times were documented as wear-time graphs using TheraMon software.[11]

The mean daily wear times were determined in 281 wear-time graphs from young patients who were treated in a private orthodontic practice in Traben-Trarbach, Germany, or in the orthodontic department of the University Hospital of Tübingen, Germany, and who had worn the appliances for a 6-month treatment period. The patients were enrolled in the study between November 2010 and May 2012. The inclusion criteria were as follows: age between 6 and 18 years; no syndromic illness; orthodontic treatment with plates or functional orthodontic appliances with an integral microelectronic wear-time gauge; wear time for a period of at least 6 months; and a checkup at least every 100 days. We enrolled 146 boys and 135 girls into the study. They were between 6 and 17 years of age (mean age, 11.6 years; SD, 2.4 years). The study was approved by the University Hospital of Tübingen ethics committee (registration numbers 128/2009B01 and 339/2012B01).

### Statistical analysis

Data analysis was descriptive. The median wear times during the first 6 months were evaluated and compared. The Shapiro-Wilks test was used to test the normal distribution of the recorded wear times, and a visual verification of the normal distribution was carried out using a histogram and a Q-Q plot.

## RESULTS

Wear-time data were not normally distributed, as shown by a Shapiro-Wilks test ($P < 0.0001$) and visual verification of the data histogram and Q-Q plot. Consequently, median values were used for subsequent analysis. The data were left-skewed, with recorded data lying above the median scattered over a large time interval. Very high (17.7 hours) and very low (1.5 hours) median wear times were observed in the cohort. The 25th percentile was 7.7 hours, and the 75th percentile was 10.2 hours. The variability of median wear times of all patients in the cohort is shown in Figure 1; 140 of 281 patients achieved a median guidance level of wear of 9 or more hours per day, although 12 to 15 hours of wear time were initially prescribed. The median wear times of less than 9 hours per day were evaluated more closely in the other 141 patients.

An unexpected large variability in wear behavior was observed over the evaluation period in some subjects, as shown by the representative examples in Figures 2, *A*, and 3. In these microelectronic wear-time graphs, the horizontal blue bar marks the target minimum wear-time range (7-8 hours/day) to ensure effective treatment. The red dotted line denotes the actual median daily wear times, and the total daily wear times are shown on the purple wear-time curve.

Figure 2, *A*, shows the characteristic wear-time graph of patients who wore their appliance every day over several months. In this representative example, the wear time varied between 6.75 and 11.5 hours per day, resulting in a median wear time of 9.35 hours per day (red dotted line). The detailed analysis (Fig 2, *B*) shows that the appliance was almost only worn at night between about 22:00 and 07:30 hours; for all wear-time graphs, the software assigns the date of the next day at midnight, and therefore the wear time for patients who only wore their appliances in the evening until early morning is spread over 2 successive days. This regular and constant wear-time pattern, without any zero wear time per day, was found in only 42 of 281 patients. In all other patients (239 of 281), the individual wear times and wear behaviors were so variable that systematic categorization of wear patterns across the entire cohort was impractical. This heterogeneity of behavior was also evident by the fact that in the 6-month study period, 238 of 281 evaluated patients did not wear their appliances every day during the treatment period.

Figure 3 shows a similar median daily wear time as in Figure 2, *A* (8.76 hours/day), but with drastically different wear behavior. This wear-time pattern is characteristic of patients who compensate for little or no wear time on some days by wearing the appliance for