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ORIGINAL ARTICLE

Visual acuity of dentists in their respective clinical conditions

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Abstract
Objectives This study examined the impact of age and magnification on the near visual acuity of dentists in their private practice under simulated clinical conditions.
Materials and methods Miniaturized visual tests were fixed in posterior teeth of a dental phantom head and brought to 31 dentists in their respective private practice. The visual acuity of these dentists (n = 19, ≥40 years; n = 12, <40 years) was measured in a clinical setting under the following conditions: (a) natural visual acuity, distance of 300 mm; (b) natural visual acuity, free choice of the distance; and (c) loupe and additional light source, if available.
Results The visual acuity under the different clinical conditions varied widely between individuals. The older group of dentists had a lower median visual acuity value under all clinical conditions. This difference was highly significant for natural visual acuity at a free choice of distance ($p < 0.0001$). For younger dentists (<40 years), visual acuity could be significantly improved by reducing the eye-object distance ($p = 0.001$) or by using loupes ($p = 0.008$). For older dentists (≥40 years), visual acuity could be significantly improved by using loupes ($p = 0.0005$).
Conclusions Visual performance decreased with increasing age under the specific clinical conditions of each dentist's private practice. Magnification aids can compensate for visual deficiencies.
Clinical relevance The question of whether findings obtained under standardized conditions are valuable for the habitual setting of each dentist's private practice seems clinically relevant.

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Introduction

Magnification devices such as loupes are used in many medical professions to improve the precision of manual work [1, 2]. Dentistry, with its small operating field, seems predestined for the use of optical aids. However, the idea that magnification devices should be used as standard equipment in dentistry is relatively new [3–6]. Over the past decades, it appears that the use of a magnification in dentistry has been growing [7, 8]. However, the body of scientific evidence about the impact of visual acuity on dental performance is weak [9–11]. Further clinically applicable research seems mandatory.

In previous studies, we described and validated new visual tests, which allow for the discrimination of near vision in dentists [12, 13]. These miniaturized tests can be used in a transparent format on a negatoscope for standardized near vision tests [12], or non-transparent and fixed in dental cavities for a simulated clinical situation [13, 14]. We found a large individual variability and an important decrease in the visual acuity with increasing age. This decrease due to presbyopia is well known [15–20] and starts already at the age of approximately 40 years [12, 13, 15, 16, 21]. However, it was shown in a university setting that magnification devices can reliably compensate for a deficient visual acuity [13].

Studies carried out under standardized conditions at a university clinic may be different to the clinical situation in a given private practice where the habitual environment is individually chosen by the dentist. The aim of the present study was to evaluate the visual acuity of dentists in their private practice with respect to magnification devices and the dentist's age.

Materials and methods

The test persons were randomly selected from the registry of the local dentist association. Inclusion criteria were an active private practice and <65 years of age. Additional dentists in the same practice were included in the study. A total of 31 dentists from 19 practices participated in the study. The dentists were classified according to their age into two subgroups (<40 years (n = 12) and ≥40 years (n = 19)) to investigate the influence of the dentist's age [12, 13].

The power analysis was based on the visual performance of 13 dentists aged between 26 and 63 years. The sample size calculation indicated that at least five dentists per group were needed to detect any significant difference between the two age groups (α error 5 %, power 80 %).

Miniaturized visual tests with E-optotypes were fixed in distal cavities of maxillary posterior teeth in a phantom head (KaVo, Biberach, Germany) as described in the study by Eichenberger et al. [13] (Fig. 1). This setting allows one to conduct a visual test in an individual clinical situation. The dimension of the E-optotypes ranged from 0.05 to 0.58 mm. The distance between the three bars of the E-optotype corresponds to the smallest detectable dimension [22]. The metric dimension of the bar spacing (e.g., 0.01) was converted into the reciprocal value (e.g.,100) to gain a positive association between the linear value and the quality of visual performance.

The visual performance was tested under the following conditions:

(a) Natural visual acuity (NV)—no magnification devices, distance of 300 mm (typical working distance), operating lamp
(b) Free natural visual acuity (NVf)—no magnification devices, free choice of the distance (typical controlling distance), operating lamp
(c) Loupe (L) and additional light source, if available; focal distance of the loupe, operating lamp

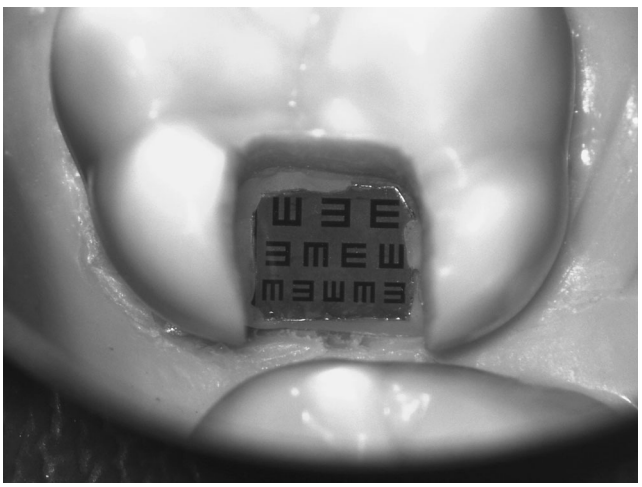

Fig. 1 The miniaturized visual tests are fixed in distal cavities of maxillary posterior teeth in a phantom head

Individual eyeglasses could be worn in all groups. The specification of the available loupes was noted. During all visual tests, the same expert supervised the eye-object distance and the reading of the E-optotypes. The smallest line that could be read was registered.

The influence of age on the visual performance in the different conditions was analyzed. Additionally, we registered the best clinical situation (NV, NVf, or L) per dentist and tested the influence of age and magnification on this value.

For statistical analysis, the software R version 2.12.2 (www.r-project.org) was used. The significance level was set at $\alpha = 0.05$. Descriptive statistics were calculated to determine medians, means, ranges, and standard deviations for the two age groups under all conditions. The influence of the dentist's age and the different clinical situations was analyzed using a nonparametric ANOVA for longitudinal data [23], followed by the exact Wilcoxon rank-sum test or sign test, whereupon the difference of only one registered line was considered as equivalent. The p values were adjusted due to multiple comparisons using the Bonferroni-Holm correction [24]. The influence of presbyopia was analyzed in a second mathematical approach. Spearman's rank correlation coefficient was used to detect a relationship between the dentist's age and NVf.

Results

Median, mean, standard deviation (SD), and range for the two different age groups (<40 or ≥40 years) are presented in Table 1. Under all three conditions, we found a wide range of visual acuity among the dentists.

The younger group (<40 years) showed a better visual acuity with less variability (range, SD) for all conditions than the group whose ages were ≥40 years (Table 1). The difference between the two age groups was not significant for NV (p = 0.054) or for the loupes (p = 0.12), but highly significant for NVf ($p < 0.0001$). This was confirmed by the Spearman's rank correlation coefficient of −0.733 that revealed a strong negative correlation between age and NVf.

Of all the dentists, 70 % (n = 22) was routinely using loupes, which was similar in both age groups (68 % ≥40 years, 75 % <40 years). One dentist used a single lens loupe, 21 used Galilean loupes with a magnification of ×2.5; Keplerian loupes with higher magnifications were not used. Three dentists (10 %) used a microscope in their practice, but these data were not included in the study due to the insufficient power for any statistical analysis. In the group aged <40 years, natural vision could be significantly improved when reducing the eye-object distance (NVf vs. NV p = 0.001). In this group, the additional benefit of loupes was small (L vs. NVf p = 0.13). In

Table 1 Reciprocal bar distance (mm^{-1}) for dentists aged <40 and ≥40 years

Condition	Median (*n*); <40 y	Median (*n*); ≥40 y	Mean (*n*); <40 y	Mean (*n*); ≥40 y	SD; <40 y	SD; ≥40 y	Range; <40 y	Range; ≥40 y
NV	13.70 ($n = 12$)	12.05 ($n = 19$)	13.77 ($n = 12$)	11.90 ($n = 19$)	1.32	2.69	[12.05; 15.63]	[8.69; 15.63]
NVf[a]	17.86 ($n = 12$)	12.05 ($n = 19$)	17.18 ($n = 12$)	12.21 ($n = 19$)	2.47	3.02	[13.70; 21.28]	[8.69; 17.86]
L	21.28 ($n = 9$)	17.86 ($n = 13$)	19.78 ($n = 9$)	16.90 ($n = 13$)	3.36	4.26	[13.70; 24.39]	[8.69; 24.39]

Notice the highly significant difference between the two age groups for NVf ([a] $p < 0.0001$) and the similar values of NVf <40 years and loupe ≥40 years.
n number of dentists; *y* years; *NV* natural vision, 300 mm; *NVf* natural vision free distance; *L* individual loupe if available

contrast, the dentists aged ≥40 years showed no significant difference between NV and NVf ($p = 0.25$), but a significantly better visual performance when using loupes (L vs. NV or NVf $p = 0.0005$) (Table 2). The NVf value of the dentists aged <40 years was similar to the visual acuity of the older dentists using loupes (Table 1).

When comparing the best available condition of every test person (NV, NVf, or loupes), the visual performance could be significantly improved in 19 of 22 dentists by using magnification devices ($p < 0.0001$). Dentists aged <40 years also showed, under the best available condition, a significantly better visual performance than dentists aged ≥40 years ($p = 0.004$).

Discussion

The newly developed near vision tests of Eichenberger et al. [12, 13] showed a high variability in the individual visual performance and an important influence of the dentist's age under standardized conditions. Magnification devices can compensate visual deficiencies. It can be questioned if the individual and self-chosen situation in a private practice would support a good visual performance over time. Thus, it was the aim of the present study to evaluate the visual performance of private practitioners in their individual clinical setting.

Due to the start of presbyopia at an age of 40 years [12, 13, 15, 16, 21], the test persons were divided into two age groups (<40 and ≥40 years old). The uneven age distribution in the registry of the local dentist association is reflected in the uneven sample size of the two age groups. Some of the 31 participating dentists were working in group practices. This might have led to selection bias concerning the choice of magnification devices, as they might have motivated each other to routinely use loupes.

Additional variables such as the light source and a reduced contrast in the cavity were part of the test setting as well as of a real clinical situation. These variables were not registered separately.

The dimension of the smallest recognized structure varied in the NVf conditions by a factor of ×2.5. Thus, some dentists could only recognize structures that were more than two times bigger than those recognized by other dentists. The distinctive variability for NVf between the two age groups could be expected. Dentists <40 years have an unrestricted accommodation and can achieve a natural magnification by reducing the working distance. Magnification and eye-object distance relate in a linear reciprocal manner. This reduced distance is part of the clinical routine to control small structures and leads to the remarkable improvement of the visual acuity from NV to NVf in the younger group ($p = 0.001$). Older dentists lose this natural magnification, and they are dependent on optical aids to improve their visual performance [15, 16, 21].

By using loupes, young dentists lose the natural magnification of NVf due to the loupe's focal distance. This distance is defined by ergonomic reasons and compromises, for young dentists, the optical performance of the loupe. In this context, it should be noted that almost all test persons used Galilean loupes with a magnification of ×2.5. It was shown in a previous study that Keplerian loupes with higher magnifications also lead, in younger dentists, to a highly superior visual performance compared to NVf [12, 13]. Therefore, the difference between natural visual acuity and loupe might be more considerable than is shown in the present study if dentists would have used Keplerian loupes. The same study [13] showed, under standardized conditions, a highly superior visual performance for the microscope which was independent of the dentist's age. The potential of the microscope to solve the discussed visual challenges in dental private practices should be considered in further studies.

Table 2 The different conditions are compared for both age groups. In dentists aged <40 years, visual performance could be significantly improved by reducing the distance (NVf) or by using loupes (L), while dentists aged ≥40 years could improve their visual performance with a magnification device only

Comparison	Dentists aged <40 y, *p* value	Dentists aged ≥40 y, *p* value
NV vs. NVf	0.001	0.25
NV vs. L	0.008	0.0005
NVf vs. L	0.13	0.0005

y years; *NV* natural vision, 300 mm; *NVf* natural vision free distance; *L* individual loupe if available

Dentists should be aware of their visual acuity and its decline over time. Optical aids should be used early enough to compensate for visual deficiencies and ensure that the best conditions are employed for good quality of dental work. The impact of visual acuity on the quality of dental diagnosis and therapy has to be investigated in further studies.

Conclusions

Magnification devices and the dentist's age have a significant influence on visual acuity under the clinical conditions of an individual's private practice. Dentists aged ≥40 years benefited the most from magnification aids. Therefore, for the older dentists, it is strongly recommended to use magnification devices in order to compensate for any visual deficiencies.

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Conflict of Interest The authors declare that they have no conflict of interest.

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