Quantitative Assessment of Enamel Hypomineralization by KaVo DIAGNOdent at Different Sites on First Permanent Molars of Children in China

Shao-Min Li, DDS Jing Zou, DDS, MS Zhengyan Wang, DDS, MS J. Tim Wright, DDS, MS Ye Zhang, BM

Drs. Li and Zou are associate professors, Department of Pediatric Dentistry, West China College of Stomatology, Sichuan University, Chengdu, Sichuan Province, People's Republic of China; Dr. Wang is PhD candidate in oral biology and Dr. Wright is professor, Dental Research Center and Department of Pediatric Dentistry, The University of North Carolina, Chapel Hill, NC; Dr. Zhang is lecturer, Women and Children Health Hospital, Xiamen, Fujian Province, People's Republic of China.
Correspond with Dr. Li at lishaom9937@sina.com

Abstract

Purpose: The purpose of this study was to identify the most caries-susceptible site of pits and fissures on first permanent molars by quantitative evaluation of the mineralization in both caries-active and caries-free children, and to provide helpful information for cost-effective, targeted prevention.

Methods: Eighty-four caries-free and 85 caries-active children were selected from 800 6- to 7-year-old children with fully erupted first permanent molars. Hypomineralization of the central fossa (CF) and lingual pit (LP) of the maxillary or buccal pit (BP) of mandibular first permanent molars were evaluated by KaVo DIAGNOdent. Statistical analysis included grouped *t* test and single-factor variance analysis and paired comparison.

Results: CF of mandibular first permanent molars had significantly greater hypomineralization than other sites. The hypomineralization of the maxillary CF is more severe than that of LP. The extent of the hypomineralization of each site at the first permanent molar in caries-active children was significantly higher than that in caries-free children.

Conclusions: Central fossae of first mandibular molars are the most hypomineralized sites in both caries-free and caries-active groups. The results suggest that preventive interventions should be targeted at the CF of mandibular molars with special concern given to the caries-active population. (*Pediatr Dent*. 2003;25:485-490)

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Caries prevention is critical for children, especially in developing countries where younger generations are acquiring more westernized dietary habits, which is expected to contribute to an increase in dental caries. The identification of a cost-effective and efficient way to prevent caries is particularly important in these developing countries due to the expense of treatment and the serious shortage of dentists. Effective detection of incipient caries and identification of specific susceptible sites are important for accurate risk assessment, which is critical to target the prevention of caries in a cost-effective manner.[1]

Enamel demineralization is the initial pathological change that precedes the progression to clinical caries cavitations. Epidemiological data show that the young first permanent molars have the highest prevalence of caries in Chinese children.[2] Fluoride provides an economic and efficient method in caries prevention, partly through superficial remineralization. However, Pearce et al[3] suggested that fluoride does not diffuse into the deep part of fissure lesions, and thus has minimal effect on slowing the progress of caries lesions. This observation is consistent with recent clinical reports that an increased proportion of caries lesion sites are found in fissures.[4] Furthermore, studies

of lesion morphology show that occlusal dentinal caries can present under a fissure that appears clinically intact, making the diagnosis of pit and fissure caries difficult.[5] The diagnostic accuracy directly affects the strategy and efficiency of prevention or treatment. Hamilton's study showed that early intervention on questionable caries lesions might not necessarily conserve tooth structures in the long run.[6] Therefore, it is critical to accurately detect incipient pit and fissure lesions and selectively apply sealants to those teeth or sites with increased risk of caries development.

Currently, visual examination and conventional radiography are widely used in the identification of caries. However, limitation in identifying early demineralization or hypomineralization exists because they are qualitative and subject to operator interpretation. For example, mirror and probe examination is only 25% accurate in detecting early caries.[7] Radiography can increase the sensitivity, but it is associated with the unavoidable hazards of ionizing radiation. To overcome the limitations of conventional methods, new noninvasive and quantitative diagnostic methods have been designed to improve detection accuracy, such as quantitative laser/light-induced fluorescence, electrical caries monitor, and digital imaging fiber-optic transillumination, etc. Recently, a laser-based instrument for the detection and quantification of caries, DIAGNOdent (KaVo, Biberach, Germany) was evaluated by researchers and dentists in vitro[8-11,12] and in vivo.[13-15] The device generates laser light, which is absorbed by tooth structure and reflected as fluorescence within the infrared region. The reflected laser light energy can be simultaneously quantified by the device and registered as a numerical value. At a 655-nm wavelength generated by the device, a healthy tooth structure reflects minimal fluorescence while the caries tooth structure exhibits higher fluorescence in proportion with the degree of caries giving elevated readings.

Studies have shown that the DIAGNOdent provides a sensitive and quantitative measurement for decreased mineral content.[16] Compared with radiographic examination, DIAGNOdent exhibited statistically significant higher sensitivity than bite-wing radiography in vivo (92%-96% vs 63%, $P<.001$),[13] providing a more significantly improved accuracy than radiography ($P\leq.001$) in vitro.[11] Studies also showed that DIAGNOdent raises diagnostic sensitivity beyond 90% in identification of lesions and the diagnosis of their severity. It is especially sensitive in detecting demineralization at the base of occlusal pits and fissures, significantly better than that of radiography.[7,8,11] Caries diagnosis of DIAGNOdent exhibited a higher reproducibility in detecting occlusal caries and a higher validity than electric measurement in vitro.[16] These data suggest that the DIAGNOdent device can be helpful in the decision-making process in relation to the diagnosis of occlusal caries and in preventive examination in a large population due to its sensitivity to decreased mineralization.

However, as shown by Sheehy et al, DIAGNOdent cannot differentiate a loss of mineralization from a lack of mineralization (ie, hypomineralization) and should be used in conjunction with other systems for clinical decision making.[17] The authors' present study aims were to:

1. quantitatively assess the mineralization of selected pits and fissures of bilateral maxillary and mandibular first molars as measured by laser fluorescence;
2. compare hypomineralization levels obtained in molars of caries-free children (dmft=0) with caries-active children (dmft≥5).

Methods

Subjects

Eight hundred 6- to 7-year-old children with full eruption of all 4 first permanent molars were randomly selected from schools in the city of Chengdu, Sichuan Province, China. The procedures, possible discomforts or risks, as well as possible benefits were explained fully to the involved children and their parents, and informed consent was obtained prior to the investigation. (IRB review was not available in China at the time the study was conducted). Natural light and a No. 5 explorer were used in grouping caries-free (dmft=0, based on the World Health Organization standard in 1987) and caries-active children (dmft≥5, beyond the mean of dmft in Chengdu). The epidemilogical data show that the mean dmft in Chengdu is 4.08. We selected the caries-active children whose dmft≤5. Subjects with fluorosis, partial eruption, tetracycline stain, generalized hypoplasia, fracture lines, cavitated lesions, and restorations of the first permanent molars were excluded. One hundred sixty-nine children were selected for this study, in which 84 children were caries free and 85 children were caries active. Tap water in the Chengdu area is not fluoridated, and the existing fluoride concentration is 0.2 ppm.

Testing sites

Each child was tested for 8 sites: the central fossae (CF) and lingual pits (LP) of the maxillary first permanent molars and the central fossae and buccal pits (BP) of the mandibular first permanent molars. Testing sequence was as follows: No. 3 CF, No. 3 LP, No. 14 CF, No. 14 LP, No. 30 CF, No. 30 BP, No. 19 CF, and then No. 19 BP.

Examiners

The examinations were completed by pediatric dentists from the West China College of Stomatology, Sichuan University, China. Four dentists participated in grouping caries-free vs caries-active children after calibration. The interexaminer reproducibility kappa value among the 4 dentists was 0.85. In preliminary experiments, 4 subjects (2 boys, 2 girls) were selected randomly from a population that excluded the 169 subjects in the study. Hypomineralization of tested sites was evaluated by DIAGNOdent, and the average value of 3 peak values was recorded. The examination was repeated after 1 week by the same dentist and on the same subjects. Intraexaminer reliability was evaluated based on results from the 2 preliminary experiments. The average kappa score for

Table 1. Manufacturer Selected Cutoff Point of DIAGNOdent Used in This Study

DIAGNOdent peak reading	Suggested clinical interpretation
<5	No lesions
≥5-<25	Initial enamel lesions
≥25-<35	Early dentine caries
≥35	Advanced dentine caries

intraexaminer reproducibility in this study was 0.92. All examinations were performed using the same dental chair and artificial lighting inside a mobile dental van.

Quantitative DIAGNOdent test

The laser fluorescence system DIAGNOdent (Model No. D88396 KaVo, Biberach, Germany, 1998) was used. The occlusal surfaces of the tested teeth were thoroughly cleaned prior to examination, since plaque, tartar, and discolorations may give false numerical values. The occlusal pits and fissures were polished by a low-speed rotating brush with nonfluoridated paste. All test sites were kept dry throughout the test. A baseline was established by placing the probe on a clean, facial surface of a clinically healthy permanent lower central incisor, and the DIAGNOdent reading was set at 0. The laser probe tip was placed on each fossa or the pits with light contact. The tip was rotated in a rocking motion around a vertical axis while scanning the surface of the site until the peak fluorescence value was achieved. The procedure was repeated 3 times, and the average peak value was recorded when these 3 data were similar. Final readings were calculated as the average peak value. The tip was cleaned by sterile water, dried by air after testing each site, and was sterilized with iodine and 75% ethanol after testing with each subject. Altogether, 5 tips were used in this study, and no wear problem was noted. The manufacturer suggested correlation of degree of caries lesion and DIAGNOdent peak value was used in this study as summarized in Table 1.

Statistic analysis

The quality of the intraexaminer and interexaminer reproducibility was calculated using Cohen's kappa statistic and the pairwise Spearman rank correlation coefficient. All the data were processed by the software STATA 5.0. Grouped *t* test and single-factor variance analysis and paired comparison were applied, accepting $P \leq .05$ as significant.

Results

A total of one hundred sixty-nine children, including 81 girls and 88 boys, were selected for this study, in which 84 children were caries free and 85 children were caries active. The gender distribution in both groups is illustrated in Table 2. The average ages for caries-active and caries-free groups were 6.9 and 6.2 years old, respectively. The average ages for boys and girls were 6.9 and 6.9, respectively. Altogether, 1,352 sites were examined in 169 subjects. Among the 1,352 examined sites, 334 (25%) sites had DIAGNOdent values below 5,914 (68%) sites had DIAGNOdent values in the range of 5 to 25, and 104 (8%) sites had DIAGNOdent values greater than 25 (Table 3).

Table 2. Gender Distribution and Average Age in Caries-Free and Caries-Active Group

	Caries (active)	Caries (free)	Average age (y)
Male	50	38	6.88
Female	35	46	6.90
Average age (y)	6.9	6.2	6.9

The level of hypomineralization determined at each test site of first permanent molars is shown in Figure 1. Among all the test sites on first molars, the hypomineralization of central fossae of the bilateral mandibular first permanent molars was significantly greater compared with that of other sites (Figure 1; $P<.005$, No. 30 CF vs No. 30 BP and No. 30 CF vs No. 3 CF; $P<.001$, No. 19 CF or No. 30 CF vs all other sites). The hypomineralization of the maxillary central fossa was more severe than that of the lingual pit with statistical significance (Figure 1; $P<.05$). No significant difference of hypomineralization between the same sites bilaterally (left vs right side) was found (Figure 1; $P>.1$). There was also no hypomineralization difference at each site of first molars between different genders (Figure 2; $P>.1$). The DIAGNOdent value distributions in both genders were similar to each other, with the highest value existing at the central fossae of bilateral mandibular first permanent molars. The DIAGNOdent mean values of each

Table 3. Distribution of Examined Tooth Sites in Different DIAGNOdent Value Ranges*

DIAGNOdent value range	<5		≥5 -<25		≥25	
Tooth site	Caries free	Caries active	Caries free	Caries active	Caries free	Caries active
3 CF	36	4	48	71	0	10
3 LP	53	11	31	70	0	5
14 CF	32	4	51	70	0	11
14 LP	47	16	37	65	0	4
19 CF	15	1	67	55	1	29
19 BP	42	11	42	66	1	9
30 CF	11	0	70	66	3	19
30 BP	46	5	37	68	2	10
Subtotal	282	52	383	531	7	97
Total sites	334		914		104	

*Distribution of all test sites in different DIAGNOdent value ranges (sample N=169, total sites=1,352). For caries-free group, N=84, total sites=672; for caries-active group, N=85, total sites=680.

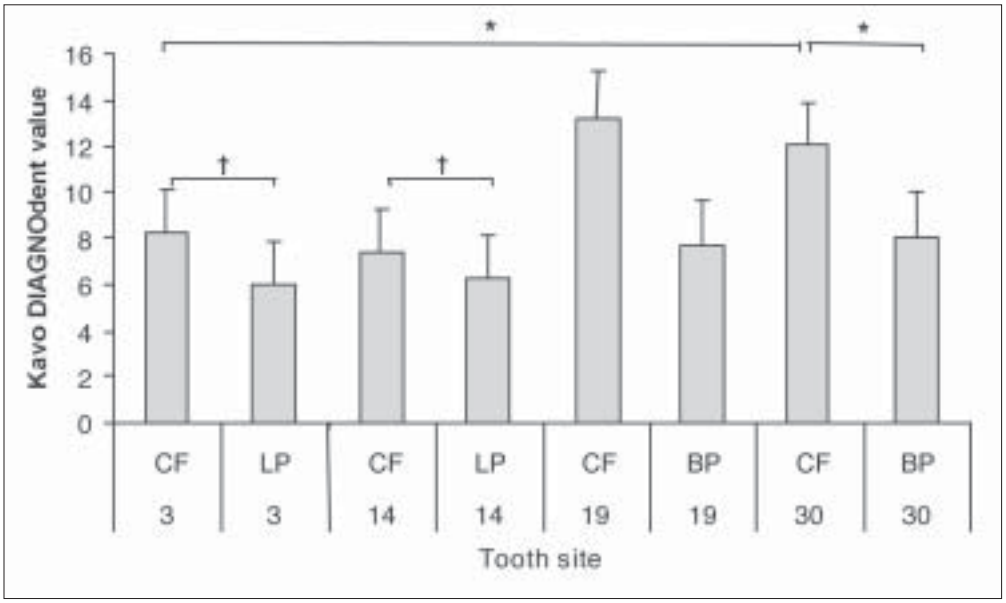

Figure 1. Hypomineralization of pit and fissure sites of the first permanent molars. No. 19 CF and 30 CF have significantly higher hypomineralization than all other sites ($P<.001$, except for $P<.005$). Nos. 3 CF and 14 CF have significant higher hypomineralization than No. 3 LP and 14 LP, respectively ($P<.05$). The bars represent mean of DIAGNOdent average peak values from all subjects at each examined site. The error bars represent standard deviation (N=169).
*$P<.005$.
†$P<.05$.

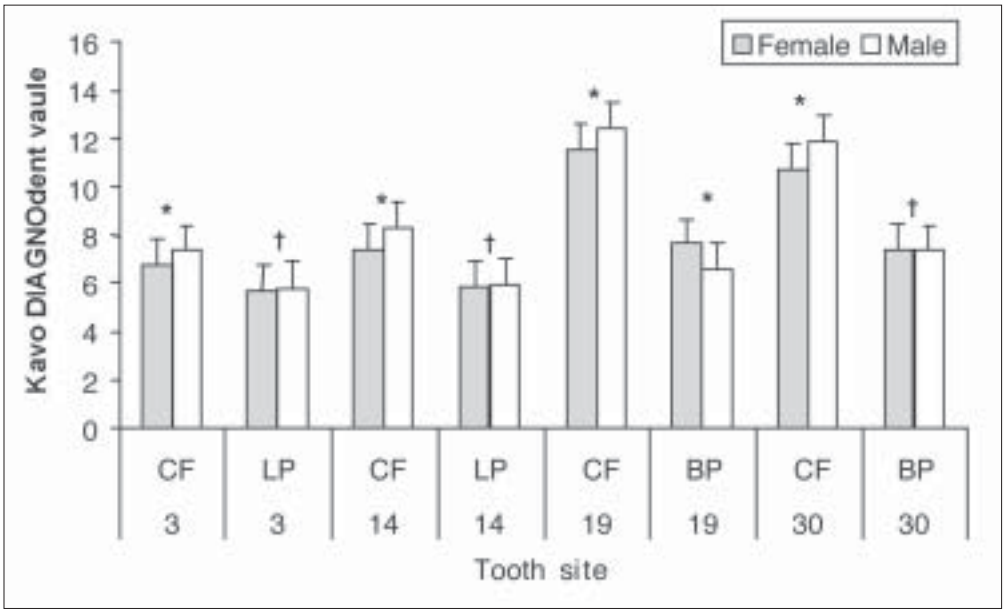

Figure 2. No significant difference in hypomineralization was found at each examined site of first molars between females and males (*$P>.1$; †$P>.5$). The bar represents the mean value of DIAGNOdent average peak values of samples from each category. The error bars represent standard deviations. For females, N=81; for males, N=88.
*$P>.1$.
†$P>.5$.

site also had a similar distribution pattern between caries-active and caries-free groups (Figure 3).

The central fossae of bilateral mandibular molars had significantly higher DIAGNOdent values (less mineral) than any other sites in both caries-active (Figure 3; $P<.005$, No. 30 CF vs No. 30 BP and No. 30 CF vs No. 3 CF; $P<.001$, No. 19 CF or No. 30 CF vs all other sites) and caries-free group (Figure 3; $P\leq.001$, No. 19 CF or No. 30 CF vs all other sites). However, the extent of hypomineralization of every test site in the caries-active children was significantly higher than that of the caries-free children (Figure 3; $P<.0001$).

Discussion

The increased incidence of dental caries in children from developing countries and the high susceptibility of young first permanent molars make providing early and cost-effective caries prevention to children of increasing importance. The results of the present study contribute valuable information for future targeted and cost-effective caries lesion prevention and monitoring of high-risk tooth sites and in high-risk children.

The authors quantitatively assessed the hypomineralization of the different caries-vulnerable pit and fissure sites of first permanent molars and identified those sites with the lowest mineral content and, thus, likely the most caries-susceptible site in visually intact and healthy teeth of 6- to 7-year-old children. The authors' results showed that the central fossae of first mandibular molars have the highest level of hypomineralization and are significantly different from all other tested sites (Figure 1). This is consistent with the report from Yang et al[18] that the central fossae of first permanent mandibular molars have the highest prevalence of caries lesions in Chinese children. The significantly higher level of hypomineralization in the central fossae of young mandibular first molars strongly suggests that targeted application of sealants on these sites could provide efficient, cost-effective caries prevention.

The preventive effects of sealant application have been evaluated in view of both clinical success and cost-effectiveness. Application of sealants to all pits and fissures regardless of risk may not provide a cost-effective preventive approach.[17] The authors' data also showed that, among 1,352 examined first permanent molar sites, about 25% had DIAGNOdent values below 5, indicating sound enamel

at those sites. The level of hypomineralization was also relatively low in the sites of lingual fissure of first maxillary molars (Figure 1). This suggests that sealant application may not be necessary in those sites. Heller et al suggested that it was more efficient when sealants were placed on incipient caries than on sound surfaces.[19] Similarly, in a retrospective study evaluating sealant effects over 5 years in an insured population, Dennison et al[20] found 2,760 sealed first molars only eliminated the need for 179 restorations. In other words, 15 sealants were required to prevent 1 first molar occlusal restoration during the 5-year study period. They suggested that sealants should be selectively applied to the most vulnerable sites of caries to have the best cost-effective prevention.

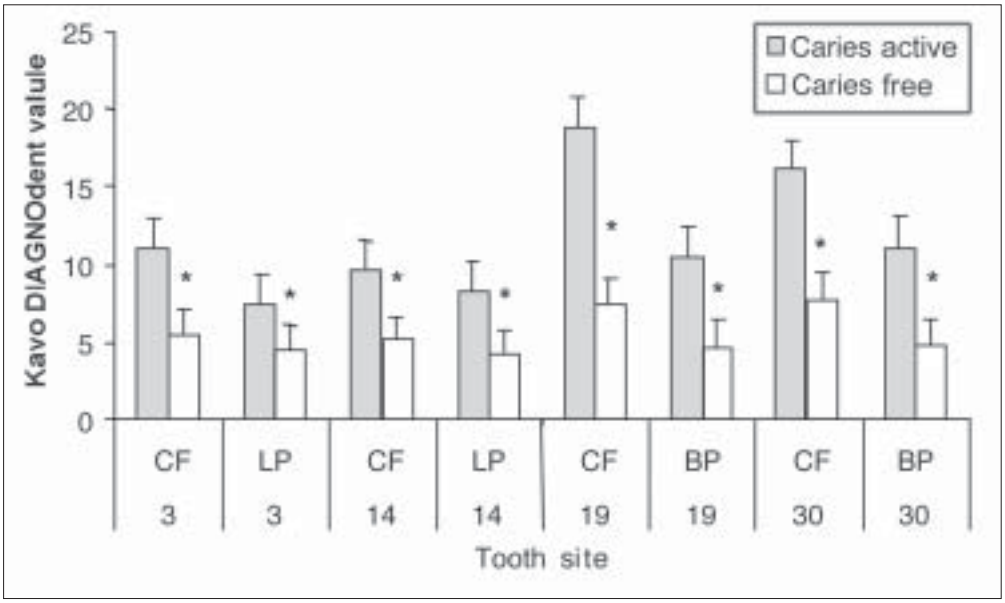

Figure 3. Hypomineralization at each examined site of first molars in caries lesion-active children is significantly higher than that in caries lesion-free children ($P<.0001$). The bar represents the mean value of DIAGNOdent average peak values of samples from each category. The error bars represent standard deviations. For caries lesion-free children, N=84; for caries-active children, N=85.
*$P<.0001$

Additionally, the authors' study showed that prevention should be targeted to high-risk, caries-active children. The authors showed that the extent of hypomineralization of the first permanent molar in caries-active children is more severe than that of the caries-free children. In fact, the authors found that in the caries-free group, most sites, except for the central fossa of first bilateral mandibular molars, have DIAGNOdent mean values lower than 5 or a normal level of mineral content. The percentage of sites with a value below 5 was 42% of all sites in caries-free group. In addition, 85% of the sites with a value below 5 were from the caries lesion-free group. On the other hand, the caries-active group only contributed to 16% of sites with a value below 5, but contributed to 58% of sites with a value from 5 to 25, and 93% of sites had a value higher than 25. The average DIAGNOdent value of most test sites in the caries-active group was higher than 5 and significantly higher than that of the caries-free group (Figure 3).

These findings suggest that in the caries-active group, more sites have advanced hypomineralization and, thus, are more vulnerable to caries progression, indicating that early prevention should be particularly emphasized on the caries-active children population. Furthermore, in evaluating the influence of dft index on sealant success, Bravo et al showed that the risk of sealant failure was increased in a high dft population.[21] Their results indicated that diligent monitoring and follow-up of sealants' retention were also necessary for successful prevention in caries-active children.

Another interesting finding of the study was the DIAGNOdent measurement distribution between 5 to 25 in caries-active and caries-free groups. Although the caries-active group had significantly higher DIAGNOdent mean values in all sites (Figure 3), the caries-free group has a similar distribution of subjects as the caries-active group in this range in central fossa measurements, and has even more subjects having DIAGNOdent values between 5 and 25 in the central fossae of bilateral mandibular molars (Table 3). The DIAGNOdent mean values of each sites have a similar distribution pattern in both groups, and the central fossae of bilateral mandibular molars have a significantly higher DIAGNOdent value than any other sites in both caries active. This finding in young permanent molars suggests 2 possibilities:

1. The central fossae of mandibular molars are demineralized more than other sites, even in the short period after eruption in both groups.
2. The central fossae of mandibular molars are developmentally less mineralized even before eruption, or they are difficult to be mineralized after eruption due to their unique anatomy.

These explanations could account for their susceptibility to demineralization and future caries development. However, the current study cannot clarify between these 2 possibilities since the authors only recorded a cross-sectional hypomineralization level, and DIANGOdent cannot distinguish developmental hypomineralization from caries-associated demineralization.[17] Future studies should investigate the dynamic change in mineralization level at those sites with a prospective design.

DIAGNOdent provided a convenient tool for detecting early pit and fissure hypomineralization and screening caries-susceptible sites in this study. Though the device had great sensitivity, early studies showed that the DIAGNOdent had a relatively lower specificity (0.82 and 0.85) than radiographic or visual detections. One factor that contributes to

false positives is an unclean tip or contaminated examination site. Since debris, deposits, stains, or calculus have different reflective properties than the healthy tooth structure, the reflection can be registered as a pathological change in enamel or dentine. Therefore, test sites should be carefully cleaned to minimize false positives and achieve accurate diagnoses of mineral levels. Another factor contributing to false positives was the DIAGNOdent's high sensitivity and the cutoff values for operative intervention.[15] This study supported the potential utility of this device as a valuable tool for detecting early hypomineralization and comprehensive caries risk assessment.

Conclusions

1. Central fossae of first mandibular molars were the most hypomineralized sites in 6- to 7-year-old children in both caries-free and caries-active groups.
2. DIAGNOdent values in the caries-active group were significantly higher than in the caries-free group, with no statistical difference between genders and bilateral sites.
3. Preventive interventions should be targeted at the CF of mandibular molars, with special concern given to the caries-active population.

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