Effect of pathological tooth wear on the content of calcium, magnesium, zinc and phosphate in human dentin

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Abstract. Aim. To compare the mineral content of the dentin of worn versus unworn teeth. Material and methods. Coronal dentin samples were collected from twenty one premolar teeth extracted for prosthetic or periodontal indications, including 11 intact teeth and 10 teeth with a significant occlusal wear. Samples were placed in concentrated nitric acid and diluted 500 times for the analysis of calcium and magnesium content and 11 times for the analysis of zinc. Contents of calcium, magnesium and zinc ions were established by means of atomic absorption spectrometry in an oxygen acetylene flame. The content of phosphorus was established by means of spectrophotometry using a test basing on a reaction of colour phosphoric-molybdenic complex formation. Data normality was assessed with Shapiro-Wilk test. Student’s t-test was used for all comparisons. Results. A statistically significantly higher content of magnesium and a lower Ca/Mg ratio were found in worn teeth at the 5% level. The concentrations of the other minerals analysed were not significantly different between the worn and intact teeth at the 5% level. Conclusion. Higher magnesium content in the dentin of human worn teeth may constitute a defence reaction to dentin exposure.

Key words: permanent teeth, mineral content, occlusal wear

Dentin is a calcified tissue of the tooth surrounding the tooth pulp and covered by enamel on the crown and by cementum on the roots. By weight, seventy percent of the dentin constitute hydroxylapatites, twenty percent – the organic matrix and ten percent – water [1]. The dentin apatites are distinct from those of the enamel, since dentin contains significant amounts of carbonate, fluoride, sodium and magnesium. Moreover, it is characterized by the presence of dentinal tubules containing fluid and processes of odontoblasts. This results in permeability, influencing its hardness, solubility as well as pain sensation [1-3]. Unlike enamel, dentin continues to form throughout life with aging or in response to caries, injury, or cavity reparation [1]. The dynamics of dentin is not fully understood.

Tooth wear is a loss of dental tissues either resulting from dental caries or acute trauma [3]. The term tooth wear describes a gradual loss of
dental hard tissues through abrasion (wear produced by interaction between teeth and other materials), attrition (wear through tooth-tooth contact) and erosion (dissolution of hard tissue by acidic substances) [4, 5]. A fourth process related to tooth wear, abfraction (mechanical and chemical wear of cervical enamel weakened by abnormal occlusal loading) has been suggested by Grippo [6].

Though anthropologists may consider human tooth wear a normal physiological phenomenon, by which over time, mastication causes tooth wear resulting in a continuum from a ‘canine-rise’ occlusion, to group function, to a flat occlusal plane with an associated edge-to-edge anterior bite [7], the soft diet of contemporary man should not cause a substantial tooth loss. Attrition and abrasion have been known to exist among hunter-gatherer populations for many thousands of years, however the prevalence of erosion in such early populations seems insignificant [7]. In particular, non-carious cervical lesions can be considered a “modern day” pathology [7]. The mechanisms of attrition, abrasion and erosion may act together, each with different intensity and duration, producing a multitude of different wear patterns [7]. The sharp enamel edges often stand out of the dentin occlusal surface, since dentin is softer than enamel and wears away quicker [3].

Magnesium constitutes a component of the enamel and dentin [8], however the role of magnesium is unclear. In the rat a higher magnesium content is found in radical than in coronal dentin [9]. Some authors suggest that differences in the mineral content of hard tissues, resulting from varied supplies during the formation of hydroxyapatites, may influence caries intensity, however, the results are contradictory [10]. It could be supposed that differences in mineralization might influence susceptibility to tooth wear, however no studies comparing the content of calcium, magnesium, zinc or phosphate in worn and unworn human teeth were found.

The aim of this study was to compare the mineral content of the dentin of worn versus unworn teeth.

**Material and methods**

The study material constituted 21 premolar teeth extracted for prosthetic or periodontal indications, including 11 intact teeth, *e.g.* without carious, abrasive or attritive lesions and 10 teeth without caries or restorations, but with visible occlusal lesions causing dentin exposure, grade 2 according to Smith and Knight [11]. The worn teeth came from 7 women and 4 men aged 35-54, whereas the intact ones were from 6 women and 4 men aged 30-57. After extraction, the teeth were stored in a dry state for a maximum of two weeks.

Intact teeth had the enamel removed with a tungsten carbide bur in a low-speed hand piece with air cooling. Subsequently, coronal dentin samples were collected both from worn and normal teeth and dentin pulver was placed in marked containers. Samples of 10 mg each prepared from dentin of individual teeth were placed in 1 ml of concentrated nitric acid. These solutions were diluted 500 times for the analysis of calcium and magnesium content and 11 times for the analysis of zinc.

The contents of calcium, magnesium and zinc ions were established by means of atomic absorption spectrometry with the use of a spectrometer PU9100X (Philips Scientific, Cambridge, UK). The readings were taken from the curve traced on the basis of Titrisol (Merck, Darmstadt, Germany) standards. For calcium, the working wave length was established at 422.7 nm, for magnesium 285.2 nm and for zinc 213.9 nm. In order to determine the content of calcium and magnesium, a 0.5% lanthanum solution (Lanthannitrat-Hexahydrat, Merck, Darmstadt, Germany) was used in order to complex phosphate and thereby prevent interference with determination of the ions of interest. The analysis was carried out in an oxygen acetylene flame (F-AAS). The content of phosphorus was established by means of spectrophotometry using the Randox Inorganic Phosphorus test (Randox Laboratories Limited, Crumlin, United Kingdom) based on the reaction of colour phosphoric-molybdenic complex formation with the use of a Lambda 40 apparatus (Perkin Elmer, Ubrlingen, Germany). For a single analysis 10 μL of the solution was taken and 1 mL of the working reagent was added. Absorbance measurements for the standard and the test were tested at a wavelength of 340 nm against the reagent blank.

The data distribution of the concentration of particular minerals as well as the proportions of calcium to magnesium, zinc and phosphorus were checked by using the Shapiro-Wilk test. Since all variables tested normal, *e.g.* p-value $>\alpha=0.05$, Student’s t-test was used for all comparisons.
Results

Data normality testing revealed a normal distribution of all variables, e.g. p-value > α=0.05. The mineral content of dentin from worn and intact teeth is presented in (table 1). Comparing the mineral content of worn and unworn teeth by Student’s t-test, a statistically significantly higher content of magnesium (p=0.0139) and a significantly lower Ca/Mg ratio (p=0.0121) (p-value ≤ α=0.05) were found in teeth with wear. The concentrations of the other minerals were not significantly different between the teeth with and without occlusal wear at the 5% level.

Discussion

In the present study the content of magnesium in coronal dentin from intact teeth was 3.12 mg/g and in dentin from worn teeth 4.04 mg/g. Higher values were reported by Derise et al. [12], who found 7.6 mg/g of magnesium in dentin with atomic absorption spectrophotometry, but the samples were made of the whole coronal and radical dentin with the cementum. It is known that a higher magnesium content is found in radical than in coronal dentin [9]. Retief et al., [13] reported an average value of 8.7 mg/g and Jenkins [14] 9 mg/g. The lower magnesium content in the present study may be due to the fact that the teeth were not dried and the water content in the tissue influenced the results of analysis, whereas in other studies reporting magnesium content in dentin [12-14] the teeth examined were dried in an oven for 8-24 hours at at least 100°C. Moreover, values obtained by different methods may not be comparable [12].

The concentration of magnesium in dentin increases with age [11,12]. However, it seems unlikely that a slight age difference between the patients with worn and unworn teeth could be responsible for the significant difference in magnesium content in the present study.

Tooth attrition causes transparent dentine formation and the production of reactionary dentine, reducing dentine permeability [15]. Mineral concentration is higher in sclerotic dentin, being consistent with increased mineral accumulation in the tubule lumens [16]. Examination of sclerosed tubules with secondary ion microscopy demonstrated the presence of magnesium, potassium and sodium [17]. In normal dentin, magnesium increases from the superficial dentin layers towards the predentine [18]. Electron diffraction patterns of the peritubular dentine allow us to state that whitlockite is present in the peritubular dentine, where about 1% in weight of magnesium is incorporated [17]. Thus intra-tubular deposition of crystals of whitlockite contributes to peritubular dentine aposition. Tubular sclerosis with whitlockite can be responsible for the increase in magnesium concentration without a significant influence on the concentration of calcium or phosphate.

Grippo [6] suggested that the mineral content of dentin may play an important role in the mechanism of tooth wear, depending on its solubility. Paschalis et al. [2] found, that dentin dissolution was retarded in the presence of magnesium

| Table 1. Mineral content of dentin from teeth with and without occlusal wear. |
|---------------------------------|---------------------------------|----------------------|----------------------|
| Mineral or ratio                | In dentin from | In dentin from   | Significance of     |
|                                | worn teeth     | intact teeth     | difference          |
|                                | (mg/g) (n=10)  | (mg/g) (n=11)    |                      |
|                                | Mean   | SD    | Mean   | SD    |                      |
| Ca                              | 249.97 | 39.82 | 266.19 | 24.60 | ns                   |
| Mg                              | 4.04   | 0.88  | 3.12   | 0.67  | p=0.0139*            |
| Zn                              | 0.266  | 0.061 | 0.272  | 0.093 | ns                   |
| P                               | 172.63 | 21.19 | 188.34 | 23.40 | ns                   |
| Ca/P                            | 1.45   | 0.17  | 1.42   | 0.08  | ns                   |
| Ca/Mg                           | 64.48  | 16.89 | 89.52  | 23.53 | p=0.0121*            |
| Ca/Zn                           | 990.28 | 292.28| 1069.23| 322.68| ns                   |

* Student’s t-test.
ns: non-significant.
ions. The hypothesis that abrasion is potentiated by erosive damage to the dental hard tissues was not supported in a recent study by Ganss et al. [19], however, these results seem to apply only to dentine in vitro, since in vivo, intraoral enzymes would break down dentine demineralised by erosion, making it vulnerable to abrasion.

It seems unlikely that dentin of a higher magnesium content without a reduced calcification could be more susceptible to wear. It can be thus supposed that the higher magnesium content in the dentin of human worn teeth results from a defence reaction of the odontoblasts to dentin exposure.

**Disclosure**

None of the authors has any conflict of interest or financial support to disclose.

**References**