Paedodontic preformed crowns in primary teeth and relative degree of dental wear

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Abstract

Aim Prosthetic rehabilitation of deciduous teeth in paediatric age using pre-formed crowns has been considered one of the best methods of dental restoration since their introduction. Their main advantages are related to durability, longevity and a low rate of recurrent cavities. Since stainless steel crowns do not coincide with aesthetic needs of parents and patients, preformed paedodontic crowns made of zirconia and nano-hybrid composite was introduced. The aim of the study is to evaluate the degree of wear on the enamel and on themselves of the different paedodontic crowns.

Materials and Methods Nine bovine teeth and nine paedodontic crowns for deciduous molars were selected for the study, three of which in zirconia, three in nano-hybrid composite and three in stainless steel. Wear test was carried out on the Rtech™ Instruments tribometer applying a force of 50 N. After that, both the bovine teeth and the paedodontic crowns were observed using a stereo microscope (Zeiss Stemi C-500) and a scanning electron microscope (SEM, Cambridge Stereoscan 440). The areas of wear were calculated with a software [ImageJ, version 1x, Wayne Rasband, Maryland, USA].

Results The zirconia crown was found to have the highest friction coefficient (0.77), while the metal crown the lowest (0.47). The zirconia crown showed the smallest wear area (0.98), while the nano-hybrid composite crown had the largest wear area (5.6). Regarding the wear of the opposing bovine teeth, the nano-hybrid composite crown caused a lower wear volume (0.00585) and wear area (1.2) than zirconia and stainless steel crowns, which achieved similar results.

Conclusion Pre-formed paediatric crowns in zirconia, nano-hybrid composite and stainless steel are a valid aid for the restoration of deciduous teeth and do not compromise the physiological wear characteristic of the phases of the dental exchange. The stainless steel crown is preferable for the restorations in the posterior sectors as its behaviour is the most similar to that of a natural tooth. Zirconia and nano-hybrid composite crowns showed an inversely proportional behaviour between their wear volume and that of the opposing tooth.

KEYWORDS Paedodontic crowns, Primary dentition, Dental wear, Paediatric Patients.

Introduction

Deciduous teeth have a fundamental importance as far as the aesthetics, occlusion, chewing, phonetics and in psycho-emotional well-being of the child, since they stimulate the development of the jaws, maintain an adequate space for the corresponding permanent teeth and affect the quality of life and development of children. Dental caries still represents one of the most widespread pathologies not only in the general population but also in the paediatric population. According to the Italian Ministry of Health it is estimated that, globally, tooth decay affects approximately 60–90% of children [Ministero della Salute, 2017]. Moreover, it is considered one of the main causes of the early loss of deciduous teeth, and this can lead to problems related to the loss of space and eruptive difficulties. Conservative treatments carried out in paediatric patients provide for the complete removal of the decayed tissue and its replacement with a biocompatible filling material having physical-chemical characteristics such as resistance to occlusal and masticatory forces and to the oral ecosystem [Ministero della Salute, 2017].

An alternative is the prosthetic rehabilitation using preformed crowns in the case of restorations of important lesions or in aesthetic areas. While it is thought that prosthetic dentistry is applied and applicable only in adulthood, it is can be used at any age with the necessary precautions, having the well-being and aesthetic appearance of the patient as the main objective [Ministero della Salute, 2017].

Guidelines provided by the American Association of Pediatric Dentistry and the British Society for Pediatric Dentistry suggest that teeth with more than two decayed surfaces, those with extensive decay affecting one or more surfaces, and those with localised or generalised developmental defects such as enamel hypoplasia, amelogenesis imperfecta and dentinogenesis imperfecta should be restored with coronal coverage [American Academy of Paediatric Dentistry, 2014; Kindelan et al., 2008; Innes et al., 2015].

Stainless steel crowns (SSC) are often the first restorative choice for primary teeth with severe hard tissue loss and have

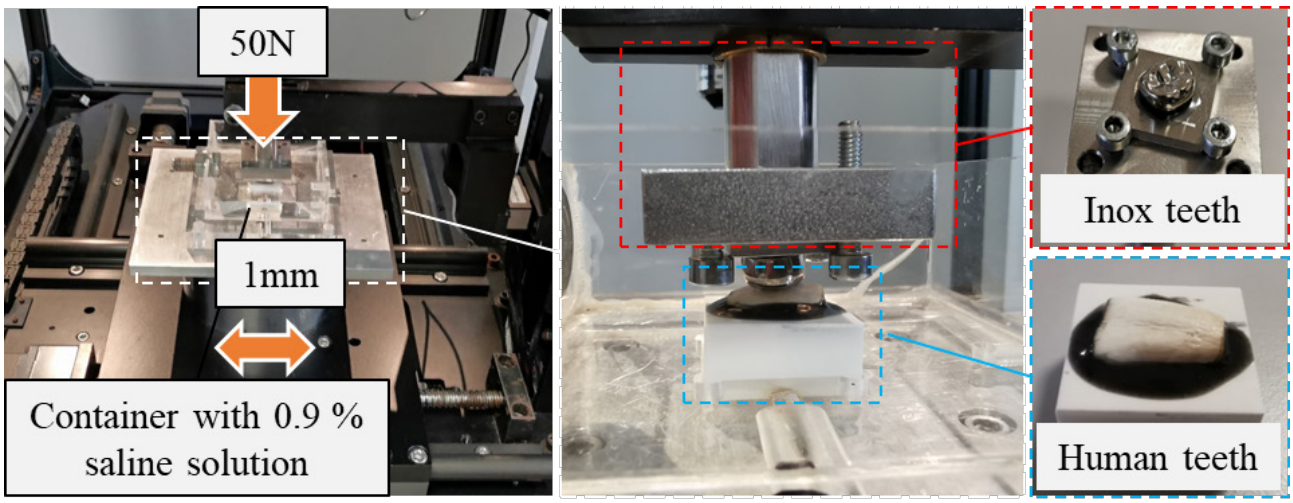


FIG. 1 Wear tests setup.

been one of the most effective restorative methods in paediatric dentistry since their introduction by Humphrey in the 1950s [Choi et al., 2016]. In particular, they are considered one of the best restoration methods for the first and second deciduous molar, with a survival time in the oral cavity that is on average higher than the time of a normal filling: 3 years after the restoration, only 1.5% of the crowns needs to be redone, unlike regular composite fillings of two- or three-surface cavities, which require a repeat in 21% of cases [Zahdan et al., 2018]. Despite advantages such as durability, longevity and a low rate of recurrent caries, SSCs do not meet the aesthetic needs of parents, patients and paediatric dentists. To overcome these difficulties, preformed zirconia (ZC) paediatric crowns have been introduced.

Thanks to their versatility, zirconia crowns present themselves as the new frontier of paediatric prosthesis: they allow total coverage even in the anterior area, often the site of trauma and carious lesions caused by ECC and baby bottle syndrome, without compromising with the aesthetic aspect [Pani et al., 2016].

Recently, highly filled, laser sintered, pre-cured nano-hybrid composite enamel shells have also been proposed. Their anatomical profiles are replicas of the natural deciduous tooth with excellent physical and highly aesthetic properties that facilitate their direct use as individual crowns for anterior and posterior deciduous teeth. They are generally cured using physical means (light, heat, pressure, etc.); as a result, they have homogeneous and pore-free surfaces, which gives good aesthetics, greater resistance to abrasion and adequate adaptation [Rojas Reynoso and Gasca Argueta, 2014].

In clinical practice, some paediatric dentists are wary of preformed paedodontics crowns as they fear that they may modify the natural dental wear process. The above-mentioned materials have different wear properties than natural teeth, which can consequently influence the wear rates of the opposing teeth. In children, wearing of the deciduous dentition is a natural process that affects all the surfaces that mostly come into occlusion, i.e. the incisal edges of the incisors and the cusps of canines and molars.

This physiological process is due to the morphological immaturity of the articular skeletal components. Rotational movements of the jaw in fact promote a remodeling and development of the temporomandibular joint in search of occlusal stability that the child will find only at the time of eruption and occlusal contact between the first permanent molars. Reduced or excessive wear of the occlusal surfaces of the teeth and dental materials can cause functional and aesthetic problems, dentin hypersensitivity, temporomandibular disorders due to the loss of vertical dimension, overeruption of opposing teeth and traumatic occlusion [Ludovichetti et al., 2019; Yip et al., 2004].

Although there are several studies on the wear of permanent teeth caused by dental materials, the previous works concerning the degree of wear of the preformed dental crowns used in the paediatric age are limited. Therefore, the aim of our study is to evaluate the degree of wear on the enamel of the different dental materials of paedodontic crowns, in order to select the optimal option for clinical practice.

Material and methods

Samples

Nine bovine teeth, free of caries and/or fractures, were selected for the study. After extraction, the soft tissue residues that had remained adherent to the surface were removed. Subsequently, the teeth were washed with a soft bristle manual brush and immersed in a 5% sodium hypochlorite solution for 1 hour. All samples were stored in a 0.9% NaCl solution containing 0.1% thymol to maintain hydration [Ludovichetti et al., 2022].

Nine paedodontic crowns for deciduous molars were selected, of which three in zirconia (Nusmile), three in nano-hybrid composite (Edelweiss) and three in stainless steel (3M), respectively divided into groups A, C and D.

The samples were glued to metal/ceramic plates using the two-component epoxy resin (Resin75, G&P Intech, Altavilla Vicentina (VI), Italy).

Wear Test

The wear tests were carried out on the Rtech™ Instruments tribometer, positioning the crowns to be tested on the upper

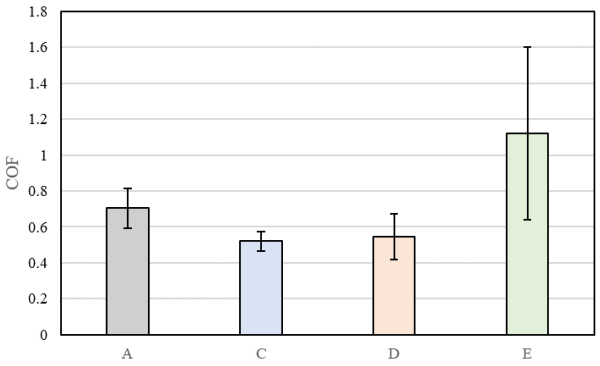


FIG. 2 Average coefficients of friction and relative standard deviation.

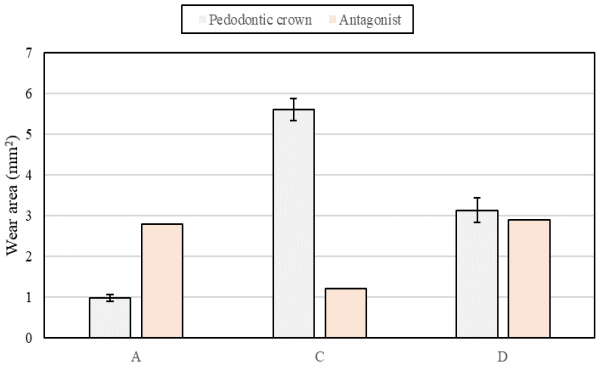


FIG. 3 Average wear area for each type of crown and their relative opposing bovine teeth.

Type	mean (sd)
Nusmile	0.77 (0.39)
Edelweiss	0.52 (0.28)
Inox	0.47 (0.39)

TAB. 1 Test friction coefficient.

support and fixing the bovine samples on a ceramic plate which was in turn fixed to the lower slide (Fig. 1). The tests were carried out applying a normal force of 50 N in a reciprocating sliding configuration with a 1 mm displacement. All tests were carried out by immersing the samples in an aqueous solution of 0.9% NaCl to recreate the environment of the human mouth. The duration of each trial was set at 50,000 seconds (approximately 833 minutes), with a movement frequency of 2 Hz, for a total of 100,000 cycles.

Microscope Analysis

After the wear tests, both the bovine teeth and the paedodontic crowns were observed using a stereo microscope (Zeiss Stemi C-500, Carl Zeiss, Oberkochen, Germany) and a scanning electron microscope (SEM, Stereoscan 440 , Leica Microsystems Cambridge, Cambridge, UK).

The SEM images were obtained by working with secondary electrons in order to highlight wear morphology. Compositional analyses were conducted on the paedodontic crowns using EDS (PV9800 EDS, Philips, Amsterdam, Netherlands) to semi-quantitatively evaluate the quantity and composition of the wear products present on the surface of the crowns. The Sensofar Plu-Neox™ (Sensofar, Terrassa, Spain) optical 3D profilometer was used to scan the wear track by using a Nikon Tu Plan Fluor (Nikon, Tokyo, Japan) 20x objective. After wear tests, the wear area of the paedodontic crowns and bovine

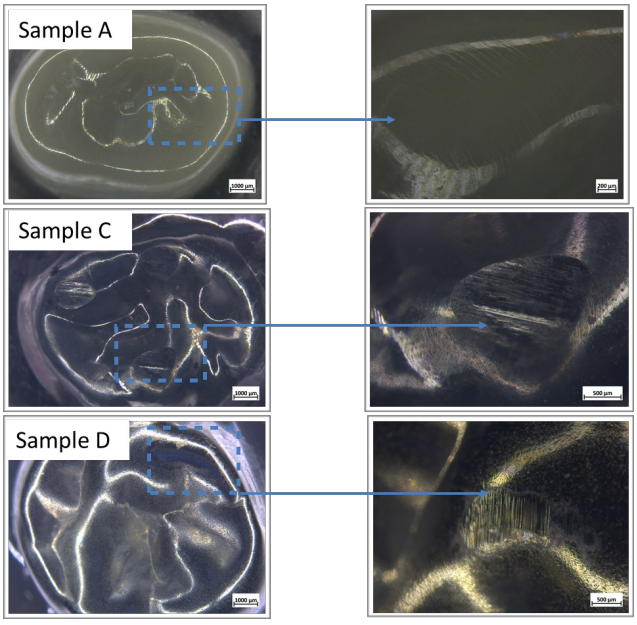


FIG. 4 Stereoscopic images at different magnifications of different types of crown.

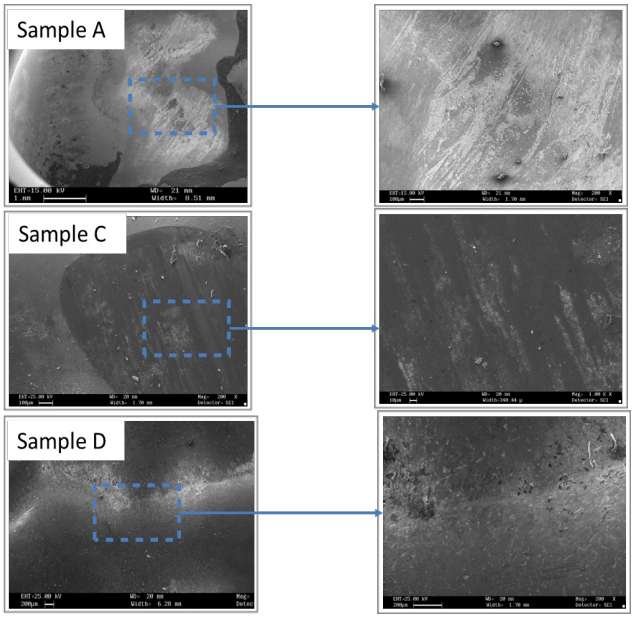


FIG. 5 SEM images at different magnifications of different types of crowns.

SAMPLES	Ca worn area Wt%	Ca unworn area Wt %	Difference
A	5.97	2.79	3.18
C	0.67	0.3	0.37
D	1.6	0	1.6

TAB. 2 Amount of Ca calculated on the basis of Fig.6.

teeth was calculated by using the ImageJ software [version 1x, Wayne Rasband, Maryland, USA].

Results

Fig. 2 displays the average coefficient of friction (COF) of different paedodontic crowns and Table 1 shows their value.

The lowest COF is achieved when samples C and D were used as crowns whereas the highest value was achieved when E is used. Sample A lies in between.

It should be noted that with the E samples an average COF > 1 was registered, making the completion of the entire test impossible.

Fig. 3 shows the wear area of the paedodontic crowns and their relative antagonist measured on the images reported in Fig. 4 and Fig. 6, respectively. A different scenario with respect to COF can be highlighted. As a matter of fact, in that case, A crowns were characterised by the lowest wear whereas the C crown by the highest one. Specifically, compared to the A case, the wear area increased by 471% and 220% for C and D, respectively.

For information on wear morphologies, SEM acquisitions of the wear scar were carried out and results are reported in Fig. 5. The images confirmed what highlighted with the stereoscopic microscope images. To evaluate if some adhesion from the counterpart was present, EDS analyses were carried out and results are reported in Fig. 6.

Quantitative results on the presence of Ca content before and after the wear test are reported in Table 2. In samples A and D, a significant change in the amount of Ca was detected, while in sample C this difference was minimal. Since Ca is derived from the antagonist's teeth, this can lead to the conclusion that the wear produced by crown C was less than

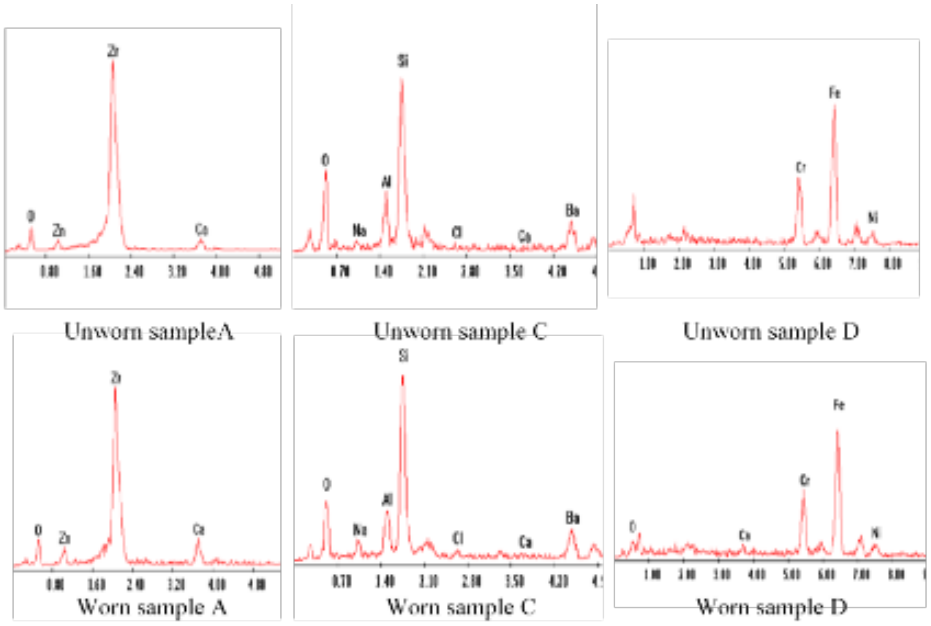
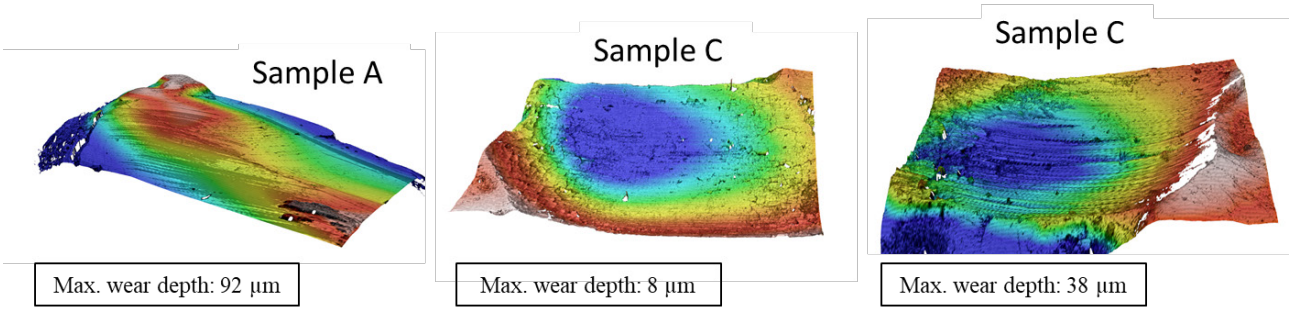


FIG. 6 Profilometer image of the wear area of the bovine tooth generated by different pedodontics crowns.

FIG. 7 EDS analysis on worn and unworn crowns surfaces.



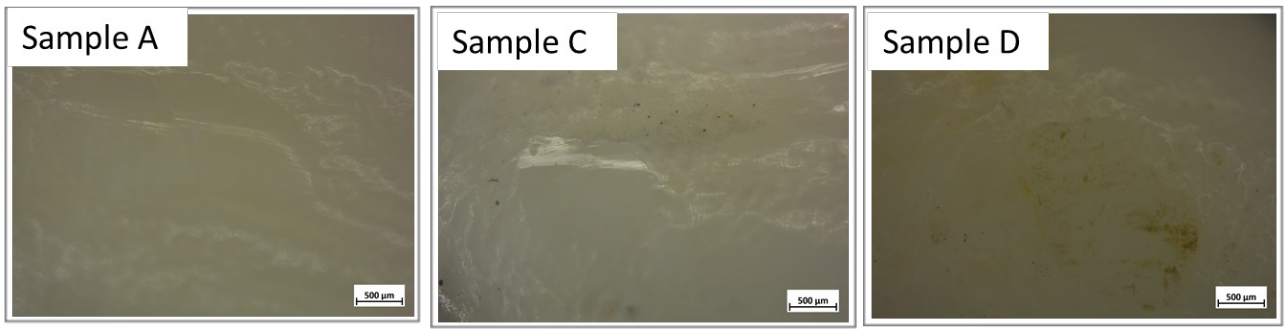


FIG. 8 Stereoscopic images of the bovine tooth used for different crowns.

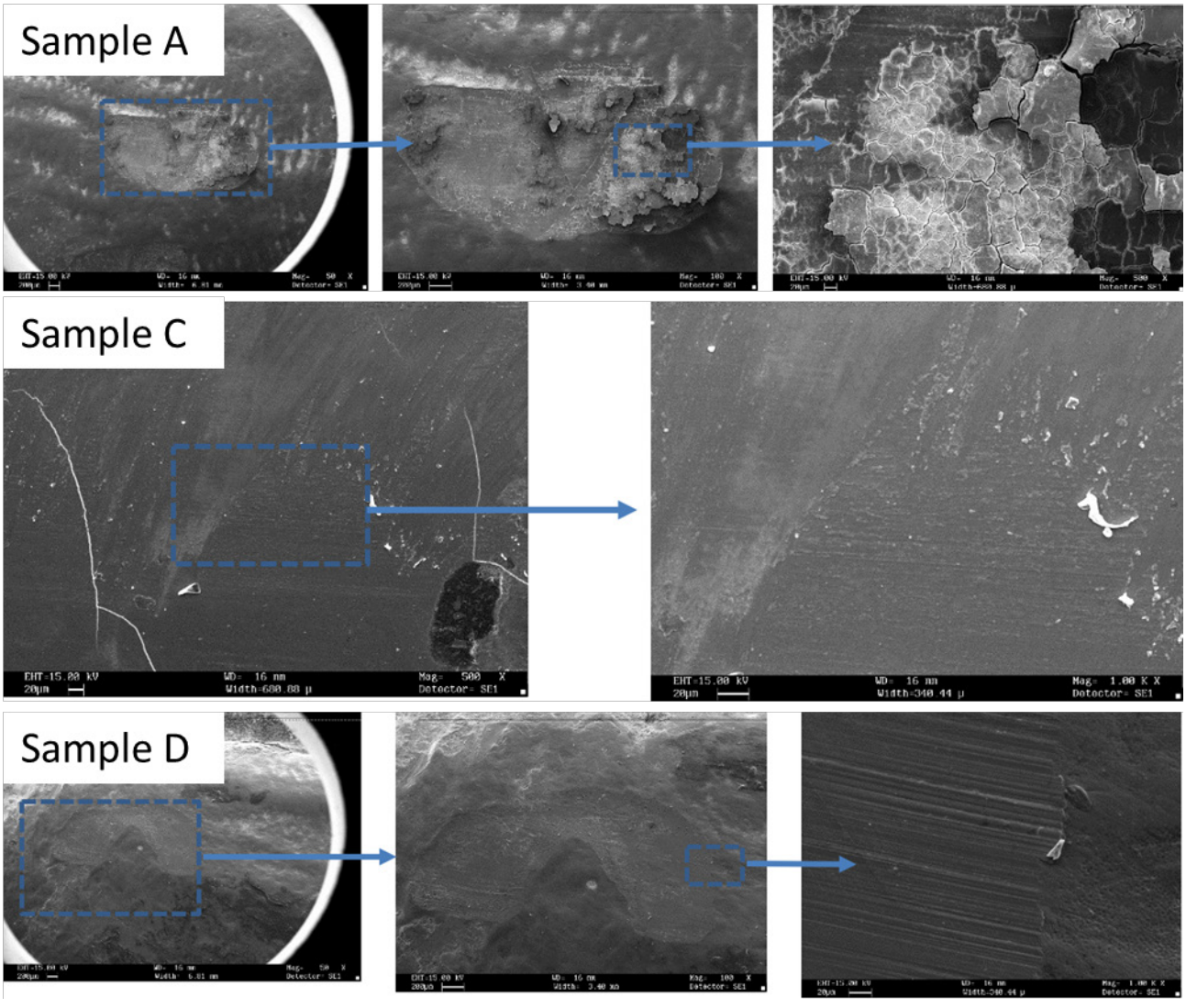


FIG. 9 SEM images at different magnifications of different types of crowns.

the others, as confirmed in Fig. 3.

Nevertheless, the wear areas of opposing teeth A and D were found to be very similar (Fig. 3), although the respective Ca content was different. To explain this inconsistency, the opposing teeth were scanned by using the optical profiler, which allowed the calculation of the depth of these traces (Fig. 7). A great difference, namely, a 142% increase, was detected between sample A and sample D, while sample B confirms the presence of the lowest wear depth.

For the sake of clarity, stereoscopic and SEM investigations were also performed on the crowns antagonists, namely the corresponding bovine teeth, and the results are reported in Fig. 8 and Fig. 9, respectively. The traces on the A and D-type antagonists appeared well-defined and marked, while the traces on the C-type bovine teeth were light and difficult to recognise.

To evaluate the presence or absence of statistical differences between the samples of the different zirconia (Nusmile), nano-hybrid composite (Edelweiss) and stainless steel (3M) paedodontic crowns, the mean Student's t test was used. Regarding the friction coefficient of the tests (Fig. 2), it emerged that the zirconia material had the highest value, while the nano-hybrid composite material had the lowest.

Furthermore, in terms of the wear area of the preformed crowns, the results showed that the zirconia material had the smallest wear area, while the nano-hybrid composite material had the largest one.

Referring, instead, to the wear of the opposing bovine teeth, on one hand the zirconia material determined a wear area on them 57% times greater than that of nano-hybrid composite material and 4% greater than that of stainless steel material. On the other hand, the stainless steel material caused 142% more wear area than the nano-hybrid composite material.

Therefore, starting from these considerations, the composite nano-hybrid composite material caused a much lower wear volume on the antagonist compared with the other materials. Considering the wear area of the opposing bovine teeth, the nano-hybrid composite material generated a much smaller wear area than the others, while the zirconia and stainless steel materials showed a similar wear area.

Discussion

In children, the physiological wear of the deciduous dentition can be compromised by the use of dental materials having wear properties different from those of natural teeth. In fact, they can influence the wear rates of the natural antagonist teeth. The enamel layer in deciduous teeth is thinner and less mineralised than in permanent teeth, however whether this layer is more prone to erosive wear remains a matter of controversy [Corica and Caprioglio, 2014]. Some in vitro studies show that deciduous tooth enamel is more susceptible to wearing than permanent teeth [Jász and Szőke,2022; Assuncao et al., 2019], while others report no difference in susceptibility [Mulic et al., 2016; Lussi et al., 2000]. Since the complexity of in vivo wear studies is time-consuming, methods for simulating wear in the laboratory have been developed. Currently, there is no in vitro protocol that can truly simulate the oral environment [Heintze; 2006].

However, chewing simulators reproduce the same conditions, additionally imitating simple movements such as grinding. This helps to compare the wear properties of different materials, thus the mechanism underlying wear resistance can be studied in the preclinical stage using specific test variables. There are several tests that can be used to study the wear performance of dental materials: for example, pin-on-block, pin-on-disk, three-body wear, and toothbrush simulation [Heintze et al., 2008].

The average value of the physiological chewing force is 50 N. Instead the number of in-vivo chewing cycles for an individual in a year corresponds to about 240,000-250,000 in-vitro chewing cycles. However, literature reviews show that in vitro the amount of wear increases with increasing number of cycles [Sulong and Aziz, 1990]. Thus, based on further studies and following the example of other authors [Choi et al., 2016, Bolaca et al., 2019], a masticatory force of 50 N, 100,000 cycles, and a horizontal movement of 1 mm were used in this study. The wear of the tested material is influenced by several factors such as hardness, contact geometry, surface roughness, microstructural characteristics, particle size, fracture toughness and patient habits[Sripetchdanond et al., 2014; Zani et al., 2021].

Increasing the hardness of the restorative material generally causes greater wear on the opposing tooth. As claimed by other researchers, the results of this study show that ZC, which has the highest hardness value among the materials tested, showed a very small wear area on the crown but caused a higher wear volume on the opposing tooth compared to other materials [Zandparsa et al., 2016; Amer et al., 2014; Mundhe et al., 2015].

In fact, ZC determined a wear area on the opposing teeth 57% greater than that of the nano-hybrid composite and 4% greater than SSC. In addition, Bolaca et al. [2019] argue that zirconia causes less wear on the antagonist than other ceramics due to its physical properties including hardness, flexural strength, fracture toughness and density, which prevent surface micro-cracking and maintain a smooth surface during wear tests.

The SSC showed a lower coefficient of friction than the ZC, exhibiting a higher wear area than ZC. A Korean research group hypothesises that this occurs because the occlusal forces are absorbed by the ductility of the steel [Choi et al., 2016]. Furthermore, smooth surfaces could reduce the wear rates of the opposing teeth, as shown in the SEM images.

Yilmaz et al. [2011] studied the wear of SSCs by evaluating cemented metal crowns harvested from exfoliated deciduous teeth and stated that the occlusal surfaces of the SSCs for the first deciduous molar were subject to wear, since the thickness of the harvested SSCs was significantly different from that of the unused SSCs . Scanning electron microscopic observation then confirmed the presence of signs of wear on the rough occlusal surfaces of the harvested SSCs [Walia et al., 2014].

Nano-hybrid composite crowns better meet the aesthetic needs of parents, patients and paediatric dentists. In accordance with the principle that generally softer materials wear faster than the harder ones [Shimane et al., 2010], the nano-hybrid composite crown obtained the highest value in terms of area and volume of wear on its surface.

Instead, it caused a smaller wear volume and wear area on the opposing material compared to the other materials, contrary to the claims of Bolaca et al. [2019] who argues that the contact of the opposing enamel with the rough surface of the composite samples, together with the production of filler particles abrasive, can explain the increased wear of the opposing teeth.

Unfortunately, there is a paucity of articles in the literature that clinically evaluate the efficacy of paediatric crowns for the restoration of primary teeth [Valenti et al., 2022]. As a result, it is difficult for clinicians to plan a course of action and present patients with the information they need to make educated choices about restoring primary teeth in children.

Despite the limitations of our in-vitro study, which cannot perfectly imitate real in-vivo conditions, we can conclude that preformed paediatric crowns in zirconia, nano-hybrid composite and stainless steel are a valid aid for the restoration of deciduous teeth and do not compromise the physiological wear typical of the stages of dental exchange. All three paedodontic crowns in fact caused wear on the opposing teeth, themselves showing signs of wear on their surfaces, compatible with what happens in the natural dentition. Although it does not represent the most aesthetic solution, the stainless steel crown is preferable for the treatment of

restorations in the posterior sector since, in relation to wear, its behaviour was the most similar to that of a natural tooth, with correct coefficient of friction and degree of wear. Conversely, zirconia and nano-hybrid composite crowns showed an inversely proportional behaviour regarding their wear volume and that of the opposing tooth.

The results obtained by analysing the literature suggest that the topic of indirect restoration although very interesting and present in the scientific panorama, requires further investigation. In the future, it may be interesting to evaluate 3D-printed prosthetic materials that represent an evolving technology in dentistry, proposed as an alternative to manufacturing with subtractive milling or conventional machining [Valenti et al., 2022].

Statements and Declarations

Authors state that they do not have any financial or non-financial interest directly or indirectly related to the present work.

Authors' contribution

- Ludovichetti Francesco Saverio: Design of the work; Data analysis and interpretation; critical revision of the article; final approval of the version to be published.
- Luca Pezzato and Rachele Bertolini: Drafting the article; critical revision of the article; final approval of the version to be published.
- Signoriello Anna Giulia: Drafting the article; final approval of the version to be published.
- Anna Giulia Signoriello and Piera Positello: critical revision of the article; final approval of the version to be published.
- Stellini Edoardo and Antonio Gracco: critical revision of the article; final approval of the version to be published.
- Mazzoleni Sergio: critical revision of the article; final approval of the version to be published.

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