Prophylometric and SEM analyses of four different finishing methods

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Summary

Adhesion is the pivot of the modern restorative dentistry. Inlays, onlays and veneers have become a valid alternative to the traditional prosthetic treatments even in the rehabilitation of extremely damaged teeth, allowing a consistent saving of sound tooth tissues.

Composite resins and dental adhesive are continously investigated and improved, nevertheless the optimization of the tooth-adhesive interface has to be considered: in fact, the long-term stability of adhesion between tooth and composite material depends on the treatment of the amelo-dentinal surfaces.

This study investigated the quality of the occlusal walls of a cavity prepared to receive an inlay and finished with four different systems: thin and extra-thin diamond coated burs, a 12-blades carbide burs and a diamond-coated tip driven by sonic instrument.

Consequently, prophylometric and SEM analyses were performed on the samples. The average roughness values recorded by the prophylometer were expressed by the parameters Ra and RZ: there is a correspondence between the numeric values and the pictures of the SEM.

The results show a better quality (low roughness values) of the surface treated with multi-blade burs, followed by the this and extra-thin diamond coated burs. The 25 micron diamond-coated tip of the sonic instrument obtains the roughest surface and a sensibly higher amount of smear layer than the other tested systems.

Key words: prophylometric analyses, sem analyses, finishing method, finishing surfaces, adhesive restorations, mod cavity, sonic system, diamond bur, tungsten carbide bur.

Introduction

Adhesive dentistry and the continuous evolution of the composite materials allowed, in the last years, to avoid metallic restorations. Esthetic materials obtain a perfect chromatic match with the tooth and in addition, they do not need a retentive cavity: this means that we will have also a big advantage from the less crown destructions, above all in the posterior teeth, where it is necessary to reproduce correctly the occlusal morphology and the contact areas between the teeth.

If a direct composite restoration is performed, it is important to control the stresses derived by the polymerization shrinkage (1, 2): in order to solve this problem, a widely employed solution is to use indirect restorations, luted by means of a thin layer of composite, since they allow to reduce the shrinkage stress. Several articles confirm the reliability of this technique i.e. by Van Djiken et al., which describe the results of an 11-years follow up of composite inlays and onlays, stressing their able to accive good durability, excellent marginal adaptation and low frequency of secondary decay (3, 4).

The long-term stability of an inlay/onlay is due to the adhesion between tooth and composite material; it is then of primary importance the treatment of the amelo-dentinal surfaces, whose aim is to make them suitable to this kind of bond. To reach this goal, some principles should be observed, encompassing a cavity preparation with smooth angles, the removal of walls who are too frail and, in the end,

a good finishing of the surfaces interested by the adhesive procedure.
Finishing is then a key passage to reach the clinical success in an adhesive restoration (5, 6). The efforts to create a perfect adhesion between tooth and composite material would then be nullified by the occurrence of defects into the enamel margin, potentially subjected to secondary infiltration of bacteria. Finishing brings to a uniformity and regularity of the margins that eliminates the asperities and the unsubstained prisms. A smooth surface makes easier the flowing of the adhesive resin and of the composite, reducing the risk to hold air bubbles that could inhibit the material polymerization (7).
The question to be answered is which kind of bur or instrument is the most suitable to prepare and finish a cavity that will be restored by means of an adhesive technique. Preparation with diamond-coated burs with high granulosity leaves great irregularities in the margins, with non-sustained enamel prisms, that could provoke a cohesive fracture into the enamel compound due to the polymerization shrinkage (8, 9). Al Omari et al. (2001) (10) affirm that the tungsten-carbide burs produce a cavity surface smoother than the one derived by the treatment with diamond-coated burs, both before and after acid etching. Other analyses reported in the Literature about tungsten-carbide burs (40 blades) stressed high roughness levels if compared to those obtained with extra-thin granularity diamond-coated burs (11, 12). On the other hand, Barkmeier, examining the finishing obtained by means of thin-granulosity diamond-coated burs and tungsten carbide burs, concluded that the first family created a final roughness, which was not appreciable if compared to the second (13-15).
A SEM study by Boyde and Knight analyzed dental surfaces prepared by means of tungsten-carbide burs and diamond-coated burs, making a micrographic evaluation of the degree of finishing. Stressing that the first burs are much more aggressive than the second (13, 15, 16). Barnes, who performed dental finishing with a wide variety of burs, confirmed these data. By means of a SEM examination, he wrote that diamond-coated burs are not recommended for the marginal finishing, and that carbide burs, used on a high-speed handpiece, produce margin almost free form imperfections (13, 17, 18). Further following articles affirm that tungsten-carbide burs leave smoother surfaces than diamond-coated burs (19, 20).
On the other hand, according to several Authors (21-23) thin or extra-thin granulosity burs should be preferred even to tungsten-carbide burs.
In order to make easier the preparation of the proximal areas and to decrease the risk to damage the nearby teeth, cavity preparation techniques based on abrasive oscillatory systems were developed. These systems exploit the action of diamond-coated points, each of which has a specific shape for a precise aim. In particular, points for the preparation of the proximal box are made by a diamond-coated side, able to finish both the margins and the walls, and a smooth, non-abrasive side turned to the nearby tooth. Wicht et al. observed the advantages and disadvantages of this kind of systems (24): sonic (Sonicsys micro + Sonicflex 2000, KaVo, Biberach, Germania) and ultrasonic (Piezon Cavity system, EMS, Nyon, Switzerland), comparing them to the traditional rotary cavity preparation systems. The last ones are faster, but sonic systems are more efficient as regards the absence of iatrogenic lesions on the nearby teeth; according to this Author, moreover, the sonic system is better than the ultrasonic systems as regards efficiency, safety of use and handling. Windeler Watson and Krejci (25, 26) compared the marginal adaptation in small proximal cavities prepared with ultrasonic (Siplus, Komet, Lemgo, Germany) and sonic systems (Sonicsys, KaVo, Biberach, Germany); even if they found better results with the first system, they also affirmed that all the margins were far from being perfect. Despite it seems that tungsten carbide burs allow to obtain a smoother surface, due to their high cutting efficiency, it is hard to avoid a damage to the adjacent teeth while one prepares a cavity with these instruments: this damage occurs with a percentage ranging from 50 to 95% of the cases (27-32), and the most unpleasant consequence of this could be the occurrence of decay in the damaged point (31, 33-36).

Aim of the study

The aim of this work is to test that is the most suitable system to finish cavities to be filled with indirect adhesive restorations, and to provide the reader with an overview on the systems available for the finishing of the cavities that will be adhesively restored. The occlusal surfaces were finished by thin and extra-thin diamond coated burs; 12-blades carbide burs and a diamond-costed tip driven by a sonic instrument; consequently, prophylometric and SEM analyses were performed on the samples.

Method and materials

20 multi-rooted teeth extracted for periodontal or orthodontic reasons were selected: they all were cavity and restoration-free. The teeth were washed with tap water and stored in physiological saline for two weeks.
A single skilled operator (more than 10 years of clinical practice) prepared a MOD cavity (for inlays) in each tooth, assisted by a magnifying device (5X, Carl Zeiss).
In every cavity the study considered the buccal and the linguo/palatal wall of the box: those walls were finished with one of the four tested systems system. A finishing system was randomly assigned to the letters A, B, C and D. All the teeth had one cavity and two walls, we assigned randomly a letter to those walls, in order to have in every tooth 2 walls finished with different technique randomly selected.
The same operator that designed the cavities, in order to reduce the variability due to the human factor, performed the finishing procedure.
The burs and the tips employed in this study are specifically described in Table 1. It should be pointed out that all of them were new, and they were used only once to finish the cavity margins.
All of the instruments tested were employed according to the manufacturer's indications:

- The burs were mounted on a high-speed handpiece that was used under copious water irrigation at 160.000 rows/minute;
- The sonic system chosen was the handpiece Kavo Sonicflex, with an oscillation width of 150 μm (level 2).

Once the finishing procedure was complete, the teeth were sectioned in order to make possible the analysis of their walls with the prophylometer: this is an instrument able to provide us with numerical data regarding the roughness of a sample. Anyway, the above mentioned data need to be filtered in order to separate the real roughness, originated by the morphology of the bur/tip, from the waviness caused by its movement, that is translated into an undulation of the profile provoked by the operator effect. To reach this goal, a Gauss filter was applied (0,8 mm) in order to remove the peaks due to the operator.

Table 1 - The table shows the finishing systems encompassed by this study, summarizing their nature, their main features and the manufacturer that produced them.

SITE	FINISHING SYSTEM	BUR/TIP ABBREVIATION	SPEED	BUR/TIP MAIN FEATURES	CODE/ MANUFACTURER
Wall A	High speed handpiece + diamond coated bur	Diam 25	160.000 rows/min	Ultrafine White code (25 μm)	3113R Intensiv
Wall B	Sonic handpiece KaVo Sonicflex 2003 + diamond coated tip	Sonic 25	Speed 2	Ultrafine White code (25 μm)	SF 34 Komet
Wall C	High speed handpiece + tungsten carbide bur	Multi 12	160.000 rows/min	12 blades	H375R Komet
Wall D	High speed handpiece + diamond coated bur	Diam 46	160.000 rows/min	Fine Red code (46μm)	846KR018 Komet

Table 2 - The table summarizes the prophylometric data relative to the tested finishing system.

BUR/TIP	Ra	Rz
Diam 25	0.9393 +/-0,05271	6,057 +/-0,5569
Sonic 25	2.911 +/-0,5010	16,34 +/- 2,443
Multi 12	0,3939 +/-0,07679	2,135
Diam46	2,136 +/-0,0571	12,89 +/-0,5985

We preferred a prophylometer equipped with a probe that was in contact with the sample (cantilever) to one with a Laser probe. This can be explained by the fact that the cantilever, considering a very narrow area, allows to obtain the best resolution: in fact, the smaller is the sample, the higher is the definition. This is confirmed by the fact that the cantilever has a resolution power of 0.06 µm (60 nm), while the laser probe reads 1 µm. The only drawback of the prophylometer is that it is not able to analyze the margins: this is why we do not consider the cervical margin, but only the axial walls.
The samples considered in this study were analyzed by means a dedicated software (Taliscan 500 Taylor Hobson Precision) that provided us with the images of the sections and with the roughness values relative to the examined area.
Applying this technique, two average values were obtained:

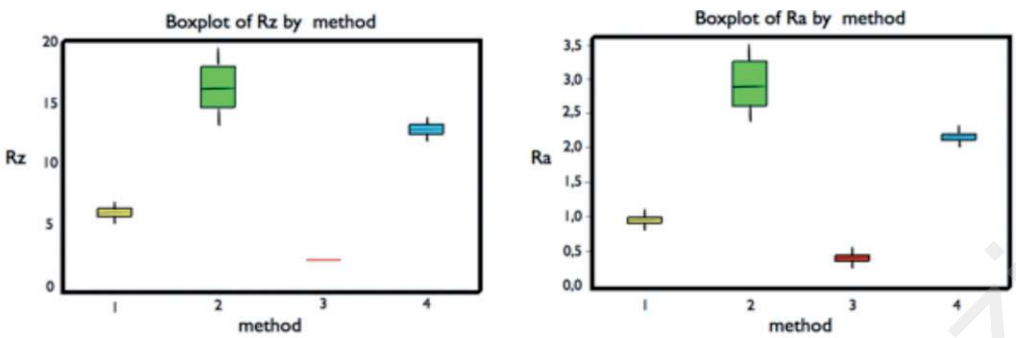
- RA is the average of the peak values recorded by the machine, and they represent the real roughness of the sample surface.
- RZ is a value that encompasses the maximum peak values recorded during the measurements, indicating the depth of the surface irregularities.

The data collected with the prophylomeer were then statistically analyzed by the software Minitab 14.0 with an ANOVA general linear model for Ra and Rz first, then a post-hoc Tukey's test was applied. The value of a was set at 0.05.
After having been analyzed with the prophylometer, the samples underwent a SEM examination at three different magnification indexes: 50x, 250x and 500x.
The examination was led by means of a S 4000 SEM (Hitachi Ltd, Tokyo, Japan) at the Anatomy Department of the University of Rome - Sapienza, Section of Clinical Microscopic Anatomy (Head Prof. Eugenio Gaudio).
In order to be examined with the SEM, the samples were prepared as follows: the samples were fixed in a 2,5% glutharaldehyde solution with a phosphate tampon (pH 7,4) for 24 hours. Subsequently, the samples were rinsed for 30 minutes and immersed for 2 more hours in a post-fix substance based on OsO_4). All of these procedures were carried out at room temperature. After this, the samples were rinsed for 30 minutes with a tampon substance, renewed every 10 minutes; then, they were dehydrated by the immersion in alcohol at increasing concentration for 2 hours. The last phase of the treatment, the critical point drying, was performed dehydrating the samples with liquid carbon dioxide. The samples were then positioned on stubs my means of a "Silver dag" sticky conductor and metalized with S150 sputer coat gold before the microscopic evaluation.
All of the samples were treated according to the above mentioned protocol.

Results

The result of prophylometric analysis of the samples (Tab. 2) can be summarized as follows:

- The sections finished by means of the diamond-coated tip run by the sonic handpiece show an irregular geometry, defined as "tapped", characterized by several furrows. The surface has a roughness, which is broadly greater than that of the other tested samples.
- Roughness values immediately lower refer to the

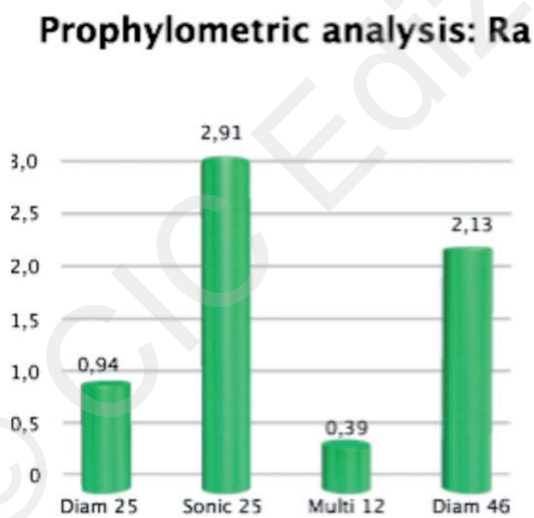


Graphic 1
Boxplot of RA and Rz prophilometic registrations.

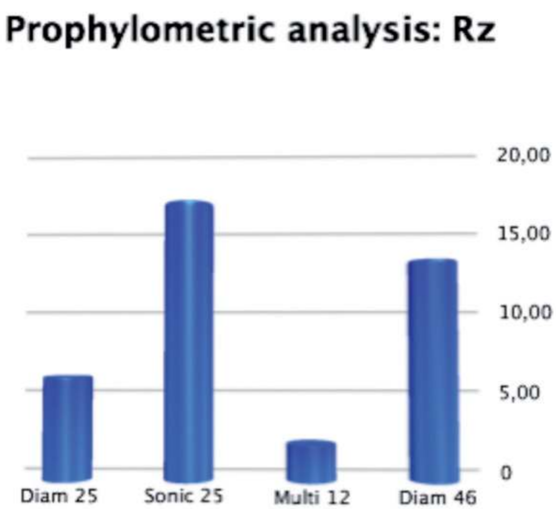
surfaces finished by means of diamond-coated burs (46 micron): this kind of bur determines deep furrows and fissures.

- The samples treated with 25 micron diamond-coated burs show a surface with regular and spread furrows and fissures.
- Lastly, the smoother surface is obtained finishing the sample with a multiple-blade tungsten-carbide bur, which practically is free from furrows and irregularities.

The graphical summary of the prophylometric registrations (boxplot Rz; Ra) (Graph 1) clarifies how high the difference among the cutting efficiencies of the tested instruments is, and how different the quality of final result can be (Graphs 2 and 3).
When it comes to the SEM examination, we can say that the data allow us to perform a qualitative analysis, while the prophylometric one is quantitative (Figs. 1-3).
The pictures of the preparations performed with a diamond-coated bur show, already at a small magnification (50x) that the diamond particles leave furrows on the tooth surface as they touch it (Fig. 1).
Another relevant outcome is that the tungsten-carbide burs, with respect to the diamond-coated ones,



Graphic 2
The hystogram shows the values of Ra recorded with the prophylometer and relative to the four finishing methods tested. It is evident how Sonic 25 and Diam 46 are inadequate to ensure a smooth surface.



Graphic 3
The hystogram shows the outcomes of the prophylometric analysis of the samples as regards Rz: in this case as well the mahjor values of surface roughness are obtained using Sonic 25 and Diam 46.

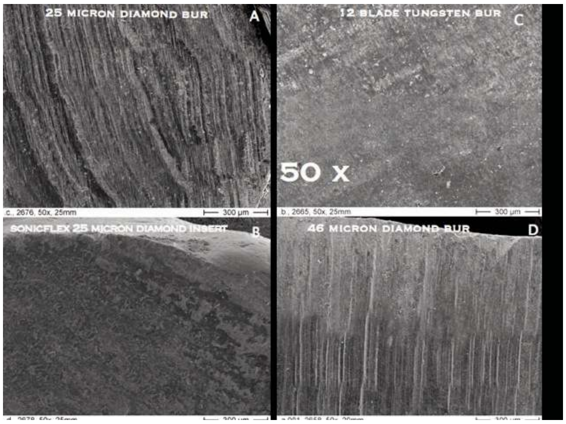


Figure 1
50x SEM microscopic view of the cavity walls finished with different methods : A) diamond coated bur 25 μm, B) diamond coated tip 25 μm, C) tungsten carbide 12 blades, D) diamond coated bur 60 μm.

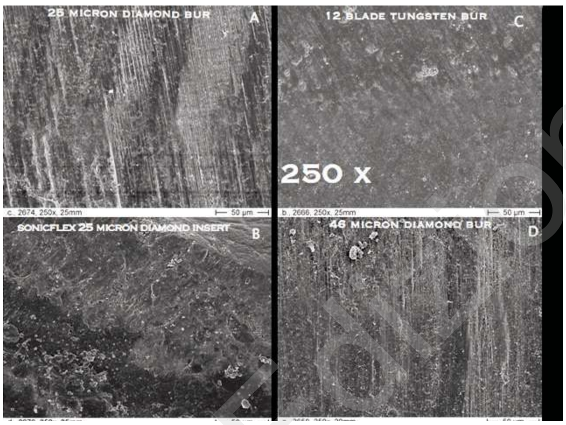


Figure 2
250x SEM microscopic view of the cavity walls finished with different methods: A) diamond coated bur 25 μm, B) diamond coated tip 25 μm, C) tungsten carbide 12 blades, D) diamond coated bur 60 μm.

leave, after their passage, a lower amount of smear layer on the surface (Fig. 3). On the other hand, the thicker smear layer is found in the surfaces finished by means of the diamond-coated tip mounted on the sonic handpiece: at a fist glance, it could look like the surface treated with this device is smoother than one prepared with burs, but this is only due to the great thickness and consistency of the debris. The greatest difference in the amount of smear layer on the samples is obviously found with the analysis at 500x magnifications. This comparison

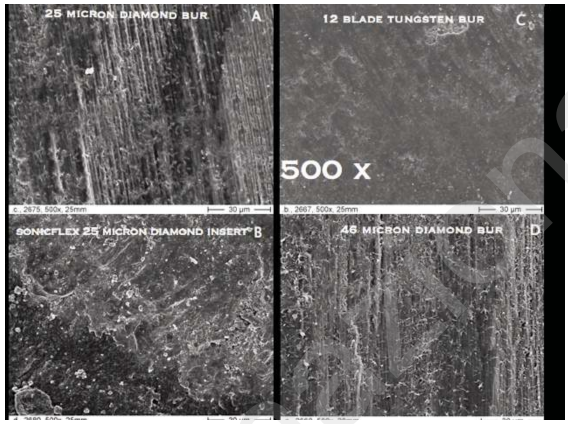


Figure 3
500x SEM microscopic view of the cavity walls finished with different methods: A) diamond coated bur 25 μm, B) diamond coated tip 25 μm, C) tungsten carbide 12 blades, D) diamond coated bur 60 μm.

could not be found in the Literature, and is only based on a careful and punctual analysis of the images and the digital simulations the we collected (Figs. 4, 5).

Discussion

It is evidenced by the observation of the computerized reconstructions obtained by the data and the graphic summaries, that the dental surfaces are sig-

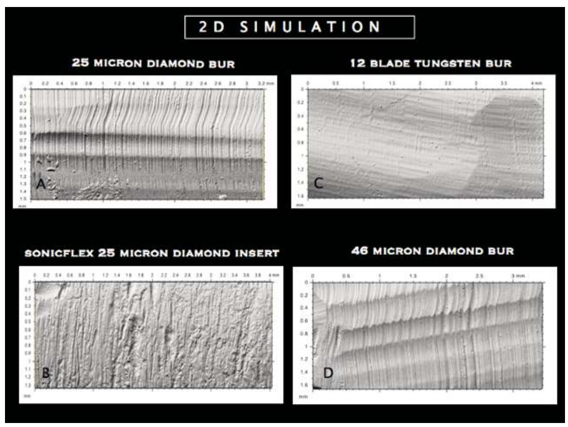


Figure 4
2d simulation of the surfaces obtained by: A) diamond coated bur 25 μm, B) diamond coated tip 25 μm, C) tungsten carbide 12 blades, D) diamond coated bur 60 μm.

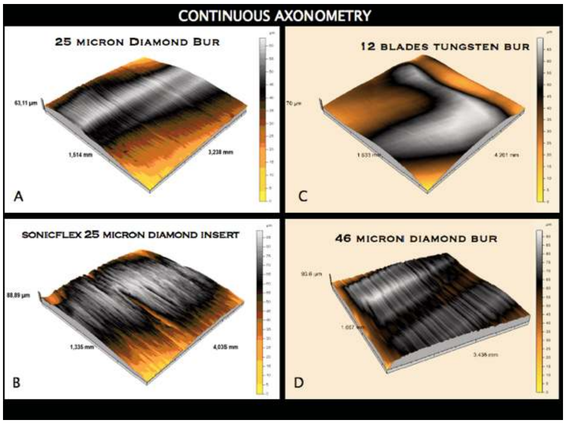


Figure 5
3d continuous axonometry obtained by different finishing method : A) diamond coated bur 25 μm, B) diamond coated tip 25 μm, C) tungsten carbide 12 blades, D) diamond coated bur 60 μm.

nificantly modified when treated with any cutting system. More specifically, the employment of a diamond-coated bur implicates the formation of a remarkable roughness on the treated surface that is the print left by the bur during its passage and is proportional to the granulosity of the diamond. This kind of micro-geography, in fact, is due to the diamond particles, that inserted on the surface of the bur in a non-homogeneous way form continuous and higgledy microscopic furrows. The samples treated with 12-blades tungsten-carbide burs, commonly considered as aggressive, presented a smooth and debris-free surface thanks to the high cutting efficiency and the precision of the blades.
The results of studies according to whom 40-blades tungsten-carbide burs produced high degrees of roughness if compared to extra-thin-granulosity diamond-coated burs and the results summarized by Barkmeier (15), are not confirmed by our data. Indeed, they are firmly refused, since, according to our results, the surface obtained by using multiple-blade burs is smoother than that obtained by means of diamond-coated burs. It is moreover important to remind that the present study adds, to the qualitative SEM analysis, the quantitative data of the prophylometer.
As previously reported by Boyde and Knight (16, 37), we found that the multiple-blade burs are aggressive towards the dental tissue but, confirming the results found by Barnes, we consider these burs suitable for the finishing procedures of the adhesive cavities, since they guarantee a good surface quality, better than the diamond-coated burs.
Nowadays, the Literature does not provide us with prophylometric studies performed with 25 μm-granulosity diamond coated burs, thus we cannot compare the values of Ra (0,9393 μm) and Rz (6,057 μm) to any other finding. Anyway, respect to the values obtained by Price and Suton, the results reported in our study can be considered as intermediate, as the bur is (its granulosity is intermediate between those of the burs that Price and Sutow tested) (20).
Moreover, comparing the values we obtained to another study, it can be inferred that the bur employed in our study has an Rz value lower than that obtained by Jung with the diamond-coated bur with the smallest granulosity (8 μm). This difference cannot be ascribed to the speed of the handpiece, since Jung used 120.000 rows per minute, while our samples were finished at 160.000 rows per minute: this means that we obtained lower roughness values running the burs with a higher speed. Anyway, our data are similar to those obtained with thin and ultra-thin granulosity diamond-coated burs by Wahle and Wendt (38).
No further comparison is possible, because in the other studies found in the Literature the Authors did not indicate the granulosity of the burs, nor the bur speed, nor the prophylometric roughness values and no microscopic image is provided.
Considering contrariwise the sonic systems, it was found that the surface is rougher and much more irregular than the others, with deep and non-linear grooves. The unique studies findable in the Literature on this topic had the aim to evaluate crown preparations, then we cannot compare them to those obtained in this research because of the different disposition of the dentine respect to that exposed in the preparation of a cavity for inlays and, lastly, for the different granulosity of the tips employed. One should be anyway aware that the tips used with sonic handpieces generally have one abrasive surface whose granulosity is higher than that of the diamond-coated burs.
Surely it is suggestible to perform further studies on this topic, in order to investigate how surface roughness affects the retentive capabilities of the common

adhesive systems on enamel end dentine. Only one paper consider this topic, Tay et al. reports that the higher bond strenght achievet (with SE bond) is the one on dentin surfaces prepared with tungsten carbamide burs, we can only suppose that it will be the same also on enamel (39).

Conclusion

Evaluating the data and considering the different aspects analyzed, a clear superiority of the multiple-blade burs issues, this leads the rejecting of the null hypothesis. It can then be concluded that, despite all the system tested gave acceptable results, the most suitable system present in the market for the finishing of the dentine in cavities to be restored adhesively is a 12-blades tungsten-carbide bur run by a handpiece whose speed ranges from 80.000 to 160.000 rows per minute.

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