ORIGINAL RESEARCH

Evaluation with Micro-CT of the Canal Seal Made with Two Different Bioceramic Cements: Guttaflow Bioseal and Bioroot RCS

Edoardo Bianco[1], Chiara Calvelli[2], Claudio L Citterio[3], Alberto Pellegatta[4], Pier M Venino[5], Marcello Maddalone[6]

Abstract

Aim: The aim of this work is to investigate the quality of root canal seals obtained by comparing two bioceramic cements, GuttaFlow bioseal and BioRoot RCS, focusing on the presence of voids created during the canal obturation procedure.

Materials and methods: The voids are analyzed using a micro-computed tomography (micro-CT) device. The study will be performed using images of the endodontic space before and after filling of a selected group of elements. Furthermore, the average thickness of the cement, the average quantity of gutta-percha compared to the total shaped volume, and the average quantity of the two cements, GuttaFlow bioseal and BioRoot RCS, with respect to the total shaped volume were considered. The apical, middle, and coronal thirds will also be investigated in a sectorial manner. Images have been analyzed using a CT-An™ software and visualized through a three-dimensional (3D) reconstruction of the slices by the software CT-Vol™. Shapiro–Wilk test/Test D'Agostino-Pearson/Kolmogorov–Smirnov test were used to ensure the reliability of results.

Results: No significant differences were observed in the amount of gutta-percha compared to the shaped volume between the GuttaFlow bioseal group and BioRoot RCS. No statistically significant difference was observed between the two groups in terms of voids.

Conclusion: The data obtained from this study allowed to conclude that the samples filled with GuttaFlow bioseal and BioRoot RCS have a similar seal capacity since no statistically significant differences were observed between the two groups. No sample showed the absence of voids within the root canal obturation.

Clinical significance: Even if the two cements tested showed differences in terms of void volume and ability to fill thin spaces, they should be considered both acceptable and equivalent in terms of clinical sealing ability.

Keywords: Abfraction, Air void, Bioceramic, Endodontic cement, Gutta-percha, Laboratory research, Micro-CT, Occlusion.

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Introduction

The endodontic treatment is the basis of all procedures designed to preserve and recover decayed dental element.[1] Cements belonging to the category of bioceramics guarantee not only a good root canal seal but also a positive interaction with the surrounding tissues. The release of calcium ions and the basic pH in fact favor the healing of periapical lesions and stimulate a process of mineralization, resulting in a real interaction with dentin. Unlike materials of the past generations, they are easier to handle, even in the presence of moisture.

The bioactivity of these cements, combined with their antimicrobial and stimulating power, makes them completely different from the materials most used in endodontic practice. To these cements, an equally satisfactory filling capacity must be added. The quality of the root canal seal that these cements guarantee can be studied using the ultra-high-resolution three-dimensional (3D) technology of the micro-computed tomography (micro-CT) and the software dedicated to it.

In the following decades, the morphology of the canal system was studied using both the techniques yet described and other innovative techniques as well as in other disciplines.[1–8]

The quality of the endodontic treatment depends on an appropriate cleaning, root canal shaping, and creating 3D model and filling obturation of the intraradicular space: the main objective to be achieved in the obturation is to reduce the formation of voids within the canal system and not to give rise to bacterial infiltration both in the apical and in the coronal directions. The various phases of therapy are essential to achieve this goal: cleaning coupled with an antibacterial effect with the ability to remove debris and smear layer derived from shaping.

Over the past 150 years, an ample selection of filling materials was tested, but no one like gutta-percha has proven to possess the suitable properties. The ideal requirements for a filling material were first set out by Brownlee and then by Grossman.[9,10]

Bioceramic cements satisfy many of these requirements as they release calcium ions, show an alkaline and an antimicrobial effect, offer a good penetration in root canals, promote tissue regeneration, and must have adequate radiopacity and good adhesion.[11,12]

[1–6]Department of Medicine and Surgery, University of Milano-Bicocca, Hospital San Gerardo, Monza, Italy

Corresponding Author: Edoardo Bianco, Department of Medicine and Surgery, University of Milano-Bicocca, Hospital San Gerardo, Monza, Italy, Phone: +39392333485, e-mail: edoardo.bianco13@gmail.com

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The aim of this work was to investigate the quality of the root canal seal obtained by comparing two bioceramic cements, GuttaFlow bioseal and BioRoot RCS, focusing on the presence of voids created during the canal obturation procedure. The analysis was performed using micro-CT images of the endodontic space before and after filling of a selected group of elements.

Furthermore, the average thickness of the cement, the average quantity of gutta-percha compared to the total shaped volume, the average quantity of the two cements, GuttaFlow Bioseal and BioRoot RCS, with respect to the total shaped volume, and the amount of voids detected in the overall canal volume were considered. The apical, middle, and coronal thirds were also investigated in a sectorial manner.

Materials and Methods

For this study 15 permanent human teeth, for a total of 24 canals, were obtained; 10 teeth were extracted from upper arch and 5 from lower arch (Table 1). Teeth were extracted at San Gerardo Hospital in Monza, and the study was conducted at the Department of Medicine and Surgery, University of Milano Bicocca, Monza.

The sample consisted of all types of tooth, both single and multiple rootlet (the single root canal was analyzed and not the whole tooth), in order to obtain a greater morphological heterogeneity of the root canal anatomy and therefore to get closer to the everyday clinical experience.

The inclusion and exclusion criteria for sample selection were as follows.

Inclusion Criteria

- Human dental elements were extracted for periodontal, orthodontic, and traumatic reasons. The elements were extracted atraumatically and without using rotating burs.
- Elements without any root fracture after extraction.

Exclusion Criteria

- Teeth with previous endodontic therapies (root canal therapy, pulpotomy, apex formation, etc.)
- Teeth with atresic endodontic system or apical resorption.

Table 1: Sample subdivision: GuttaFlow bioseal and BioRoot RCS

Tooth number	*Root canals*	*Type of instrumentation*	*Type of cement*
21	1	Reciproc	GuttaFlow bioseal
34	1	Reciproc	BioRoot RCS
15	1	Reciproc	BioRoot RCS
47	2	Reciproc	GuttaFlow bioseal
18	3	Reciproc	BioRoot RCS
37	3	Hyflex	GuttaFlow bioseal
34	1	Hyflex	GuttaFlow bioseal
24	1	Hyflex	BioRoot RCS
14	2	Hyflex	GuttaFlow bioseal
24	2	Hyflex	GuttaFlow bioseal
24	2	Hyflex	BioRoot RCS
33	1	Hyflex	BioRoot RCS
25	1	Hyflex	GuttaFlow bioseal
15	2	Hyflex	BioRoot RCS
14	1	Hyflex	BioRoot RCS

The teeth used in this work were incorporated into a transparent thick epoxy resin (Artidee® XOR Crystal®, Lindenberg, DE). It is a transparent and glossy bicomponent epoxy formulation suitable for incorporation of organic objects. It was chosen because the material shows a good degree of hardness and transparency. It also has a radiopacity that does not interfere with the micro-CT analysis. For the mixing of the resin, the instructions provided by the manufacturer were followed.

A cylindrical metal mold with a height of 4 cm and an internal diameter of 3 cm was used for casting. Inclusion took place in two phases. In the first phase, a resin base of about 1 cm was created. Subsequently with the help of a layer of blue wax, the dental elements were positioned and immersed in a second resin casting up to the level of the anatomical crown. In this way, easy orthograde access to the root canal system was allowed. The wax also allowed to avoid the occlusion of the apical foramen by the material.

The use of the micro-CT allowed a quantitative and qualitative evaluation of the preparation of the root canals in the three dimensions of the space. The micro-CT equipment used for the analysis was a SkyScan 1176 (SkyScan® Bruker Biospin).

In order to obtain the best image quality and therefore analyze in detail the root canal system, the maximum resolution of the machine (9 μm) was used. The volumetric reconstructions were automatically reprocessed by the software with an axial pattern of 9 μm cuts. Moreover, in order to have further details on the root, canal, and chamber anatomy of the elements, cross sections were made starting from the axial ones using the DataViewer software (SkyScan®). Also thanks to the software it was possible to obtain 3D volumetric reconstructions of the root canal filler, cross sections of the root that allow to evaluate the canal width, and finally an axial reconstruction to evaluate the canal form and the area of the latter along the entire length of the root.

Canal Shaping

The elements were subjected to canal shaping using two different types of nickel titanium instruments. A group of 5 teeth was instrumented using Reciproc Instruments, the remaining 15 elements were shaped by Hyflex according to the manufacturer's prescriptions.

The working length was calculated based on the measurements derived from the two-dimensional micro-CT images, since the apical detector could not be used due to the resin inclusion of the elements.

Access to the pulp chamber was obtained using a red handpiece with Intesiv 206 cutters, and Butt cutters were mounted for the finishing of the chamber walls. Mechanical instrumentation was associated with the use of root canal irrigants: 5.25% sodium hypochlorite and 17% EDTA.

Canal Obturation

In the next phase of the work, the samples were subjected to root canal obturation. Since time has elapsed between the two phases, due to the micro-CT scans, we again decided to previously irrigate the shaped canals.

It was carried out by washing with EDTA. At the same time, ultrasounds were used for 1 minute using a Satelec device with an insert dedicated to canal irrigation (satelec punta irrisafe).

Finally, the samples were subjected to washing with distilled water and dried with paper cones.

For root canal obturation, the teeth were divided into two groups: in one group, the filling material includes gutta-percha cones and GuttaFlow bioseal; while in the second group, gutta-percha and BioRoot RCS cones are used.

The elements have been divided, so that each group consists of 12 channels, and the present canals were instrumented with both Hyflex and Reciproc. The division of the samples took place randomly but guided by the following criteria:

- The two groups must have the same number of channels. In the GuttaFlow group, 3 of the 12 channels were instrumented with Reciproc and 9 with Hyflex. In the BioRoot group, 5 of 12 channels were instrumented with Reciproc and 7 with Hyflex.
- Multirooted teeth must have the same obturation method to avoid mixing cement through possible root canal communication and errors during the micro-CT image analysis phase.
- The two groups must be as homogeneous as possible in relation to the root canal instrumentation and the types of teeth present.

Respecting these criteria, the teeth were divided as presented in Table 1.

The obturation technique used to complete the obturation of the endodontic system was on the method of the single cone without vertical compaction. In fact, the cold technique is indicated by the producers of BioRoot and GuttaFlow bioseal. The bioceramic cements in fact harden in the presence of moisture, absorbing water from the surrounding environment and going against a slight expansion. Any use of heat during the hot compaction techniques of gutta-percha can alter the environment of the canal space and interfere with the hardening of the cement itself.

The elements after filling were scanned at the micro-CT for the third time (Fig. 1)

The CT-Analyzer (CTAn), the software used for the analysis of the scans, is an application for measuring quantitative parameters and reconstructing 3D models starting from micro-CT scans obtained through SkyScan devices. The CTAn (SkyScan®) allows to manage the reconstructions of 3D volumes and, by creating a customized algorithm of plug-ins, to calculate volumes and surfaces.

The focus was, therefore, on the study of:

- Volume of gutta-percha
- Cement volume
- Shaped volume and presence of voids in the canal seal

From these values, others were obtained:

- Volume of voids: obtained as the difference of the shaped volume minus the blocked volume.
- Total volume obturated: sum of the volume occupied by cement and gutta-percha.

Different task lists were created, one for the reconstruction of the shaped volume, one for the reconstruction of the gutta-percha volume, and one for the volume of the canal cement. From each task list, a 3D reconstruction of the isolated and analyzed volume was obtained.

Statistical Analysis

Statistical analysis was performed using the GraphPad Prism 7 software.

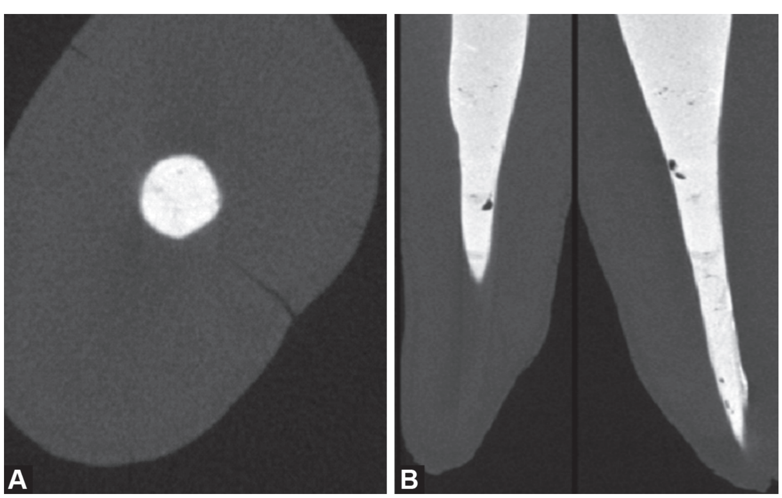
Shapiro–Wilk, D'Agostino–Pearson, and Kolmogorov–Smirnov tests were performed to asses the statistical normality. Student *t* test was performed for data with normal distribution, while Mann–Whitney *U* test was performed for data otherwise. Statistical significance was set at $p < 0.05$.

For each sample, the root canal volume is divided into three sections (the apical, middle, and coronal third). For each section, we calculated the amount of vacuum present. After performing the normal tests, the data collected for each third were analyzed in order to assess whether there is a significant difference in the meanings between the considered root canal portions.

Results

The 15 dental elements belonging to the study were divided into two groups consisting of 12 canals each, with respect to the criteria mentioned above. The samples underwent a root canal shaping phase and an endodontic obturation phase using two different types of bioceramic cements examined for this study. The following tables show the results for the two groups (Tables 2 and 3).

Since this study aimed to evaluate the quality of the root canal seal in relation to the presence of voids left by the sealer within the endodontic space, attention has been given to how these voids are distributed along the canal. The volume of interest analyzed previously was then divided into three portions (one apical area, one middle, and one coronal); and for each of them, a new search for the voids was carried out (Tables 4 and 5).



Figs 1A and B: (A) Micro-CT section: cross sections of the filled root that evaluated the canal width; (B) Axial section to evaluate the canal form and the area of the latter along the entire length of the root

Table 2: GuttaFlow bioseal group

Tooth number	Canal	Shaped volume (mm^3)	Cement volume (mm^3)	Gutta-percha volume (mm^3)	Filled volume (mm^3)	Voids' volume (mm^3)	% of vacuum on the shaped total V/S	% of gutta-percha on the shaped total G/S	% of cement on the total shaped C/S
21	1–1	5.88613	2.70339	2.85861	5.56206	0.32407	0.055056548	0.485651863	0.459281395
47	ml 1–1	11.88553	5.59248	2.81223	8.40471	3.48082	0.292861993	0.236609558	0.470528449
47	d1–1	7.53497	4.438	2.37087	6.80887	0.7261	0.09636402	0.314648897	0.588987083
37	mv 1–1*	4.53553	1.52299	2.90142	4.42441	0.11112	0.024499893	0.639709141	0.335790966
37	mp 1–1*	5.64597	2.1982	3.34958	5.54778	0.09819	0.017391166	0.593269181	0.389339653
37	d1–1	4.85896	1.64396	3.1958	4.83976	0.0192	0.003951463	0.657712762	0.338335776
34	1–2	5.24016	2.153	2.72022	4.87336	0.3668	0.069997863	0.519110104	0.410865317
14	v 1–1*	5.43473	1.91822	2.58013	4.49835	0.93638	0.172295588	0.474748516	0.352955897
14	p 1–1*	5.61397	2.7698	2.62132	5.39112	0.22285	0.039695616	0.466928038	0.493376345
24	v 1–1	5.09938	1.77423	2.94608	4.72031	0.37907	0.074336488	0.577732979	0.347930533
24	p 1–1*	4.51678	2.22171	1.89438	4.11609	0.40069	0.088711427	0.419409402	0.491879171
25	1–2	5.24016	2.14515	2.72018	4.87334	0.35641	0.069997756	0.519110002	0.410865426

*There are 2 root canals that are confluent

Table 3: BioRoot RCS group

Tooth number	Canal	Shaped volume (mm^3)	Cement volume (mm^3)	Gutta-percha volume (mm^3)	Filled volume (mm^3)	Voids' volume (mm^3)	% of vacuum on the shaped total V/S	% of gutta-percha on the shaped total G/S	% of cement on the total shaped C/S
34	1–1	12.44597	4.4684	2.38522	6.85362	5.59235	0.449330185	0.191645971	0.359023845
15	1–1	9.79776	2.6983	3.01724	5.71554	4.08222	0.416648295	0.307952022	0.275399683
17	m1 1–1	4.15843	1.02263	1.1965	2.21913	1.9393	0.466353888	0.287728782	0.245917329
17	m2 1–1	3.86084	1.19293	2.61299	3.80592	0.05492	0.014224884	0.676793133	0.308981983
17	d1–1	4.57031	1.50484	2.96853	4.47337	0.09694	0.021210815	0.649524868	0.329264317
24	v 1–1	4.14711	0.81163	3.14215	3.95378	0.19333	0.046618006	0.75767221	0.195709783
24	v 1–1	6.25572	2.5992	2.66705	5.26625	0.98947	0.158170442	0.426337816	0.415491742
24	p1–1	8.18512	3.45689	3.42672	6.88361	1.30151	0.159009275	0.418652384	0.422338341
33	1–1	5.05038	2.09273	2.89564	4.98837	0.06201	0.012278284	0.573350916	0.4143708
15	v 1–1*	3.72962	1.70313	1.94859	3.65172	0.0779	0.020886846	0.522463415	0.456649739
15	p 1–1*	5.74826	2.66818	3.07863	5.74681	0.00145	0.00025225	0.535575983	0.464171767
14	1–1	7.61420	2.40287	3.40369	5.80656	1.80764	0.237403798	0.447018728	0.315577474

*There are 2 root canals that are confluent

Table 4: Data regarding voids' distribution in the apical, medium, and coronal third of GuttaFlow bioseal group

Tooth number	Canal type	Voids' apical third (mm^3)	Voids' medium third (mm^3)	Voids' coronal third (mm^3)
21	1–1	0.17685	0.19333	0.12226
47	ml 1–1	0.24190	0.12028	0.02303
47	d1–1	0.16491	0.47280	1.93224
37	mv 1–1*	0.05233	0.03296	0.06844
37	mp 1–1*	0.01560	0.05384	0.03662
37	d1–1	0.06661	0.00012	0.00149
34	1–2	0.00020	0.0001	0.00011
14	v 1–1*	0.31383	0.36554	0.02184
14	p 1–1*	0.25866	0.21408	0.05923
24	v 1–1	0.09927	0.01041	0.04418
24	p 1–1*	0.03651	0.07319	0.13754
25	v 1–1	0.04591	0.02154	0.08569

*There are 2 root canals that are confluent

Table 5: Data regarding voids distribution in the apical, medium and coronal third of Bioroot RCS group

Tooth number	Canal type	Voids' apical third (mm^3)	Voids' medium third (mm^3)	Voids' coronal third (mm^3)
34	1–1	1.6588	1.95197	1.98158
15	1–1	0.2662	0.08871	3.18951
17	m1 1–1	0.07218	0.00044	0.2695
17	m2 1–1	0	0.00634	0.15152
17	d1–1	0.00672	0.00983	0.21741
24	v 1–1	0.00277	0.0001	0.00833
24	v 1–1	0.181	0.03731	0.54105
24	p1–1	0.07631	0.06822	0.91504
33	1–1	0.0092	0.05234	0.80351
15	v 1–1*	0.01043	0.0113	0.09756
15	p 1–1*	0.00108	0.00379	0.14698
14	42736	0.22462	0.73982	1.16293

*There are 2 root canals that are confluent

Table 6: Cement % volume of BioRoot RCS and GuttaFlow bioseal at fixed thickness

Tooth number	*Canal type*	*Voids' apical third (mm^3)*	*Voids' medium third (mm^3)*	*Voids' coronal third (mm^3)*	*Canal cement*
21	o1–1	0.17685	0.19333	0.12226	GuttaFlow bioseal
47	o1–1	0.24190	0.12028	0.02303	GuttaFlow bioseal
47	m1 1–1	0.16491	0.47280	1.93224	GuttaFlow bioseal
37	m2 1–1	0.05233	0.03296	0.06844	GuttaFlow bioseal
37	d1–1	0.01560	0.05384	0.03662	GuttaFlow bioseal
37	v 1–1	0.06661	0.00012	0.00149	GuttaFlow bioseal
34	v 1–1	0.00020	0.0001	0.00011	GuttaFlow bioseal
14	p1–1	0.31383	0.36554	0.02184	GuttaFlow bioseal
14	o1–1	0.25866	0.21408	0.05923	GuttaFlow bioseal
24	v 1–1*	0.09927	0.01041	0.04418	GuttaFlow bioseal
24	p 1–1*	0.03651	0.07319	0.13754	GuttaFlow bioseal
25	v 1–1	0.04591	0.02154	0.08569	GuttaFlow bioseal
34	o1–1	1.6588	1.95197	1.98158	BioRoot RCS
15	ml 1–1	0.2662	0.08871	3.18951	BioRoot RCS
17	d1–1	0.07218	0.00044	0.2695	BioRoot RCS
17	mv 1–1*	0	0.00634	0.15152	BioRoot RCS
17	mp 1–1*	0.00672	0.00983	0.21741	BioRoot RCS
24	d1–1	0.00277	0.0001	0.00833	BioRoot RCS
24	o1–2	0.181	0.03731	0.54105	BioRoot RCS
24	v 1–1*	0.07631	0.06822	0.91504	BioRoot RCS
33	p 1–1*	0.0092	0.05234	0.80351	BioRoot RCS
15	v 1–1	0.01043	0.0113	0.09756	BioRoot RCS
15	p 1–1*	0.00108	0.00379	0.14698	BioRoot RCS
14	v 1–1	0.22462	0.73982	1.16293	BioRoot RCS

*There are 2 root canals that are confluent

The voids in the apical third had a mean value of 0.122 mm^3 for GuttaFlow bioseal group and 0.209 mm^3 for the BioRoot in the apical third.

With Mann–Whitney *U* test, the *z* score is 0.47883. The *p* value is 0.63122. The result is not significant at $p < 0.05$, so the difference in the presence of voids in the apical portion of the teeth analyzed is not statistically significant.

The voids in the medium third had a mean value of 0.129 mm^3 for GuttaFlow bioseal group and 0.265 mm^3 for the BioRoot in the apical third.

With Mann–Whitney *U* test, the *z* score is 0.47883. The *p* value is 0.63122. The result is not significant at $p < 0.05$, so the difference in the presence of voids in the medium portion of the teeth analyzed is not statistically significant.

The voids in the coronal third had a mean value of 0.211 mm^3 for GuttaFlow bioseal group and 0.790 mm^3 for the BioRoot in the apical third.

With Mann–Whitney *U* test, the *z*-score is 0.47883. The *p* value is 0.63122. The result is not significant at $p < 0.05$, so the difference in the presence of voids in the coronal portion of the teeth analyzed is not statistically significant.

The percentage of cement distributed within two defined thickness ranges: 0.018 to 0.054 mm and 0.054 to 0.089 was also calculated using a specific task list. These values represented the smallest thicknesses that can be calculated in the program and therefore allow to evaluate the fluidity of the material (Table 6).

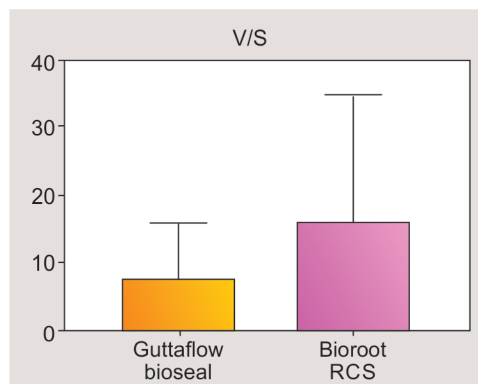


Fig. 2: Medium percentile values of cement on shaped (C/S)

With regard to gutta-percha compared to the shaped volume, no statistically significant difference was observed between the GuttaFlow bioseal group and the BioRoot RCS group (Fig. 2).

No difference was observed in the percentage of cement distribution between the two groups (Table 7).

Discussion

The success of the endodontic treatment depends to a large extent on a 3D filling of the root canal in order to prevent bacterial residues and their toxins from infecting the periapical tissues.[16,17] For this purpose, many filling materials and root canal cements have

Table 7: Canal filling BioRoot RCS and GuttaFlow bioseal groups

Tooth type	*Canal filling (%)*	*Canal cement*
34	55.07	GuttaFlow bioseal
15	58.34	GuttaFlow bioseal
18	53.36	GuttaFlow bioseal
18	98.58	GuttaFlow bioseal
18	97.88	GuttaFlow bioseal
24	97.75	GuttaFlow bioseal
24	84.18	GuttaFlow bioseal
24	84.1	GuttaFlow bioseal
33	98.77	GuttaFlow bioseal
15	97.91	GuttaFlow bioseal
15	99.97	GuttaFlow bioseal
14	76.26	GuttaFlow bioseal
21	94.49	BioRoot RCS
48	70.71	BioRoot RCS
48	90.36	BioRoot RCS
37	97.55	BioRoot RCS
37	98.26	BioRoot RCS
37	99.6	BioRoot RCS
34	93	BioRoot RCS
14	82.77	BioRoot RCS
14	96.03	BioRoot RCS
24	92.57	BioRoot RCS
24	91.13	BioRoot RCS
25	96.32	BioRoot RCS

been developed. Gutta-percha is commonly used with cement to get the maximum seal. The root canal cements in fact fill the gap between the gutta-percha and the dentine walls, creating a real glue between the two. For this reason, cements are essential for the long-term success of root canal treatment.[18]

The main cause of failure of endodontic therapies is in fact due to the bacterial micro-infiltrations that may occur between the cement and dentin, gutta-percha and cement, or through voids created in cement. Therefore, the quality of root canal filling and consequently the success of the therapy depend to a large extent on the sealing capacity of the root canal.[11] Although gutta-percha and traditional cements have commonly been used for the obturation of endodontically treated teeth, this has not really overcome the problem of infiltrations. So new materials have been developed in order to improve the seal of endodontic obturation.

Bioceramic cements have recently been introduced into endodontics. Their composition based on calcium phosphates, zirconium oxides, calcium silicates, calcium hydroxides, alumina, etc. made them particularly biocompatible and bioactive toward biological tissues, so as to stimulate the healing process, the production of mineralized tissues, and an antibacterial effect given by the alkaline pH and the release of calcium ions.

Still few studies are available in the literature concerning this category of cements, and most of them focus on the analysis of their excellent biological properties. For this reason, in this study it was decided to focus on the analysis of their behavior within the root canal when used in association with gutta-percha to obtain an ideal endodontic seal.

The evaluation of the quality of obturation and of the presence of voids left by the materials (the actual cause of the micro-infiltrations) was made by using the micro-CT.

No significant difference was observed in the amount of gutta-percha compared to the shaped volume (percentage value) between the GuttaFlow bioseal group and BioRoot RCS, as can also be seen from Figure 2, representing the volume averages.

These data would further be verified if the percentage of the filled volume with the shaped volume was considered. Also in this case, we can see from the graph how the samples filled with gutta-percha and cement BioRoot RCS are less filled than the canal space of the group obturated with GuttaFlow bioseal. Taking into account that the quantity of gutta-percha is almost similar in the two groups, the difference is attributable to the amount of cement.

It is not possible to explain these results exclusively referring to a different expansion of the two materials. It is known that bioceramic cements, as opposed to traditional cements, have a slight expansion during the hardening phase due to their tendency to absorb water from the environment, in particular from the dentinal tubules. Only few studies are available in the literature; however, precise data do not yet exist that allow to quantify the actual degree of expansion of each bioceramic cement.

In Gandolfi et al. study, it was clear how the calcium silicate GuttaFlow bioseal and MTA Fillapex cements have a greater degree of water absorption compared to cements of different composition.[19] However, only the data are referred to this study and the literature does not offer similar studies referring to BioRoot RCS.

Reasoning on the method used to insert the cement inside the canal seems more likely to be the actual cause of the difference in the GuttaFlow bioseal group and BioRoot RCS. In the case of GuttaFlow bioseal, the manufacturer offers a syringe containing the base and the catalyst of the cement itself. When injecting the material, the two substances are mixed at the level of the syringe nozzle, allowing the mixing also in the insertion inside the canals.

BioRoot RCS, in contrast, is not equipped with any self-mixing means. The product is supplied in the form of powder and liquid plus a measuring cup for the correct dosage of the powder.

Despite the results and conclusions just reported on the data on cement, the statistical analysis tells us that the difference in the average percentages of voids in the two groups depends on the case. Basically, therefore there is no real difference between the two groups in terms of voids and therefore we could consider the similar seal capacity for the two cements. From Figure 3 we can still see how the average voids present in the canals of the BioRoot group is double compared to the GuttaFlow group.

This could also be due to the way as to how it is inserted into the canal. A manual process in which the powder and liquid are mixed and then positioned inside the syringe, not allowing to have a tight control on the incorporation of air bubbles that do not guarantee a uniform and compact cement application inside the channel.

By evaluating how the voids are distributed within the canals of the BioRoot RCS group, it has been observed that the largest volumes of voids are found at the level of the coronal portion in an amount almost three times higher than that in the apical and middle thirds. This is also confirmed by the statistical data.

In the GuttaFlow group, however, the voids are distributed more evenly, and no statistical significance was observed between the average of the voids in the different third parties (Fig. 4).

Among all, it is important to evaluate the apical seal as this area represents much of the success of endodontic therapy.[20,21] Bacterial

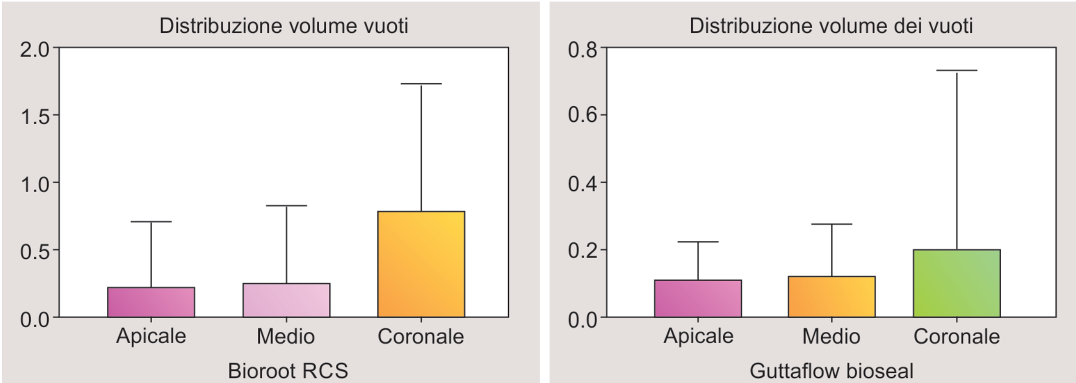


Fig. 3: Medium percentile of voids volume on shaped volume (V/S)

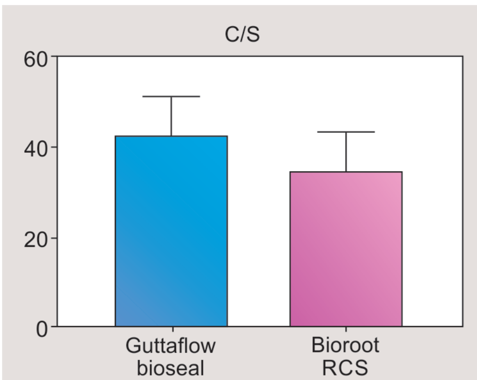


Fig. 4: Voids' volume distributions in the apical, medium, and coronal third for the GuttaFlow bioseal and BioRoot RCS groups

penetration, in fact, has an easy access from the apex where at the same time it is more difficult to control during the shaping, cleaning, and obturation phases.

As regards the percentage of cement distributed in the thickness ranges 0.018–0.054 and 0.054–0.089, no significant difference was observed between the groups, so the two cements show a similar degree of fluidity and therefore the ability to distribute in the thinner and more tortuous lateral canal structures. In general, these cements have greater thickness compared to traditional cements; in many cases, they do not even fall under the ISO 6876 standards; this, however, is not important, as these cements do not go against contraction, but conversely tend to expand, and therefore cannot undermine the quality of the seal from this point of view.

In our study, only 9 of 24 samples obtained similar results. Of these, six belong to the BioRoot RCS group and three to the GuttaFlow group (Table 6).

In analyzing the data related to the root canal filling, we find that the BioRoot RCS group has a greater number of cases with a percentage of root filling >97. These data seem to contrast with what has been described so far regarding this cement.[13–15,18] Actually we can think that the discrepancy in the range of filled volume (53.36–99.97%) in the BioRoot RCS group can depend not only on the bubbles already present in the material but also on the degree of pressure applied to the syringe during insertion of cement in the canal. This factor is operator dependent and once again we can partially relate it to the mode of application of the cement. Comparing the filling values for GuttaFlow bioseal, it has been understood that these are more homogeneous (range 70.71–99.60%) and probably related to a prefilled syringe as well as a thin and more flexible plastic needle.

Limitation of the Study

A limit of this study is the small number of teeth analyzed and that only one method of cement application was tested; thus, it would be interesting to reevaluate the potential of the BioRoot RCS which showed a lower average percentage volume within the cement-filled canals by modifying its application technique in root canals.

Conclusion

Endodontic treatment is sometimes fundamental to restore tooth integrity and a correct and balanced occlusion.[3,22–29] In this study, GuttaFlow bioseal and BioRoot RCS were compared with the single gutta-percha cone obturation technique. They seemed to have a similar seal capacity. None of the samples showed absence of voids within the root canal obturation, and no statistically significant differences was observed between the two groups.

BioRoot RCS and GuttaFlow bioseal showed a similar degree of fluidity. At the same time, however, the BioRoot RCS cement showed a lower average percentage volume within the filled canals. This has been attributed to the technique of inserting the BioRoot RCS cement into the channels.

Clinical Significance

Although the two cements tested showed differences in terms of the volume of voids and ability to fill thin spaces, both the cements should be considered acceptable and equivalent in terms of their clinical sealing ability.

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