original research article

COMPARATIVE CLINICAL STUDY BETWEEN ZIRCONIUM-CERAMIC AND METAL-CERAMIC FIXED REHABILITATIONS

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SUMMARY

Objective. This research represents a comparative study between metal-ceramic and zirconium-ceramic fixed prosthesis; it evaluates the maintenance of the prosthesis mechanical, functional and aesthetic characteristics few years after functional implantation.

Methods. The study participants were 46 in total: 26 rehabilitated with a metal-ceramic fixed prosthesis and the remaining 20 with a zirconium-ceramic prosthesis. 13 male patients in the age range of 36-63 years and 13 female patients in the age range of 33-83 years (average age of 49.5 years) composed the metal-ceramic group. 11 male patients in the age range of 39-60 years and 9 female patients in the age range of 22-59 years (average age of 54.1 years) formed the zirconium-ceramic group. The study population only included patient with fixed prosthesis on three mandibular elements and absence of first inferior molar. The abutment teeth were both natural and vital or treated with endodontics: in any case, no periapical or periodontal lesions were present; at the beginning of the procedure, the patients displayed a healthy periodontium, no sign of bone reabsorption, stable occlusion and natural opposing dentition. Patients showing bruxism and poor oral hygiene were excluded from the study. All the participants gave their written informed consent.

Results. The cases treated with metal-ceramic prosthesis resulted "excellent" in 57.14% of cases, "acceptable" in 39,16% of cases and only 3.70% "to remake". The results regarding the patient treated with zirconium-ceramic prosthesis during the entire follow-up period were "excellent" in 52.0% of cases, "acceptable" in 44.0% of cases, "to remake" in 4.0% of the cases.

Conclusions. Our study demonstrates that none of the 28 metal-ceramic cases and none of the 25 zirconium-ceramic cases has been subject to substructure fractures. Both methods demonstrated a seven-year extremely high survival rate, with almost overlapping percentages of 96.3% for metal-ceramic and 96,0% for zirconium-ceramic. The confronted methods demonstrated to be adequate for the target rehabilitative therapy. The masticatory load is greatly tolerated by the respective substructures, which did not show any inclination to fracture.

Key words: zirconium, metal ceramic, fixed dental prosthesis, comparative clinical study, fracture resistance.

Introduction

Nowadays, the increasing availability of suitable materials and a conservative dentistry's attitude allow efficient recovery of otherwise avulsion-fated teeth. During the years, prosthetic techniques tried to adapt to an increasing demand of high bio-aesthetic quality (1). The contingent interest from the dental market leads to an expansion of "all-ceramic" systems proposals, which could guarantee excellent aesthetic performances, an elevated biocompatibility and an adequate mechanical resistance (2). The various ceramic-based systems, which rapidly developed during the last years, revealed an optimal

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capacity of mirroring natural tooth aesthetic while overcoming the main limits of conventional metal-ceramic restorations. However, conventional metal-ceramic systems exhibit marginal finishing, biocompatibility and mechanical resistance that are still difficult to replicate with other materials (3, 4).
This research represents a comparative study between metal-ceramic and zirconium-ceramic fixed prosthesis; it evaluates the maintenance of the prosthesis mechanical, functional and aesthetic characteristics few years after functional implantation.

Materials and methods

The study participants were 46 in total: 26 rehabilitated with a metal-ceramic fixed prosthesis and the remaining 20 with a zirconium-ceramic prosthesis. 13 male patients in the age range of 36-63 years and 13 female patients in the age range of 33-83 years (average age of 49.5 years) composed the metal-ceramic group. 11 male patients in the age range of 39-60 years and 9 female patients in the age range of 22-59 years (average age of 54.1 years) formed the zirconium-ceramic group. The study population only included patient with fixed prosthesis on three mandibular elements and absence of first inferior molar. The abutment teeth were both natural and vital or treated with endodontics: in any case, no periapical or periodontal lesions were present; at the beginning of the procedure, the patients displayed a healthy periodontium, no sign of bone reabsorption, stable occlusion and natural opposing dentition. Patients showing bruxism and poor oral hygiene were excluded from the study. The participants were informed in advance about techniques, procedures, materials used, possible alternatives and possible reasons for therapeutic failure. Prior to the prosthetic rehabilitation, each patient has been subject to an oral hygiene session and to conservative therapy; each of them was encouraged to maintain adequate oral hygiene conditions and was subject to regular recall sessions and a follow-up every six months. All the participants gave their written informed consent.
The Co-Cr "Remanium Star" alloy (Dentaurum Italia, Italy) was utilised for the metallic structure: Ips-Inline ceramic (Ivoclar Vivadent, Schaan, Lichtenstein) was used for the ceramic cladding. The zirconium-ceramic bridges were built by using the system Cercon Zirconia (Dentsply Sirona, Germany).
The prosthetic abutments were assembled with the same technique for both metal-ceramic and zirconium-ceramic prosthesis. Abutment preparation guidelines consisted of a 1-mm-wide circumferential chamfer, axial reduction of 1 mm, and occlusal reduction of 1.5 to 2 mm (1).
A dental impression was taken using alginate ISO 1563, Kromopan (Lascod, Italy). The impression was further refined with Elite Model Fast plaster (Zhermack, Italy). During the same session, face-bow recordings were obtained with the face-bow transfer Arcus (Kavo, Germany). The combined articulator was the Protar-Evo (Kavo, Germany).
The laboratory models were employed to build a diagnostic product with "Star Wax C" wax (Dentaurum, Italy); the same wax was used to develop a silicon mask for Zetalabor condensation (Zhermack, Italy); the silicon mask was employed for the Mock-up assembly, which was obtained with an acrylic resin (Sinto-dent, Italy). The provisional craft was rebased and cemented with temporary cement Temp Bond NE (Kerr Dental, Italy). After four weeks, every abutment was re-evaluated considering soft tissues healing process. After 15 days, a dental impression was taken with a number 08 or 10 retractor wire soaked into aluminium sulphate. The latter impression was taken with the double impression technique, using silicon and adding Elite HD+ (Zhermack, Italy); it was further developed with type IV extra-hard plaster, Elite rock (Zhermack, Italy).
The models were assembled in a Protar-Evo articulator (Kavo, Germany). Their substructure was tested on abutments to evaluate passivation, marginal closure and adequate thickness for a correct ceramic stratification process. Once complete, the prosthesis was cemented with

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definitive cement. The same technique was applied to both metal-ceramic and zirconium bridges; first, abrasive blasting was carried out using Al2O3 of 110µ at 2,5 bar and a glass ionomer cement-the GC Fuji I (GC Corporation, Japan).

The conditions of the prosthetic products were monitored for data collection as time passed. We adopted the evaluation form approved by the CDA (California Dental Association Quality Evaluation System) (Table 1): on which basis we elaborated a scheme concerning the product colour, surface, anatomical shape and marginal integrity; under each parameter, we can find individual evaluation details further subdivided into acceptable and unacceptable. In accordance with a recent publication (5), we incorporate "surface" and "colour" under a single evaluation class and we maintained the other two categories as single ones under the names of "anatomical shape" and "marginal integrity". We assigned the number 1 for "surface and colour", the number 2 for "anatomical shape" and the number 3 for "marginal integrity". An evaluation letter further identified each of these aspects: "a" for "excellent", "b" for "acceptable" and "c" for "to remake". The follow-up of the 28 metal-ceramic prosthesis lasted between 85 and 16 months, with an average of 53.8 months. The follow-up of the zirconium-ceramic prosthesis lasted between 77 and 9 months, with an average of 49.6 months.

Results

The cases treated with metal-ceramic prosthesis resulted "excellent" (57.14%), "acceptable" in 11 cases (39.16%) and only in one case (3.70%) "to remake". There were 8 cases with only one "b" (80.0% of total "acceptable"), only a case with two "b" (10.0%) and one case with three "b" (10.0%). For eight cases (80.0%) the "b" was about "marginal integrity", for two cases about "anatomical shape" and for four cases (40.0%) about "colour and surface". The total number of dental elements showing little imperfections is 32; 17 of those (53.1%) belong to the category "3-marginal integrity", more precisely 13 (49.6%) show "discolouration of the margin between restoration and dental structure" and 4 prosthesis show grooves along the margins, which do not extend over the dentin-enamel junction. Small colour and/or surface defects appear over 11 (34.4%) dental elements; in particular, 6 teeth (18.7%) presented a slightly porous or rough restoration surface and 5 teeth (15.6%) presented a small discrepancy in colour, shade and/or translucency. The category "2-anatomical shape" comprehends 4 dental elements (12.5%) with "vestibular flatness", a characteristic shortened as "SFA". Let us consider the data starting from the delivering time of the metal-ceramic prosthesis. During the first three years, all the treated cases were included in the category "excellent". In between 36 and 48 months half of the cases was "excellent" while the other half "acceptable". In between 4 and 5 years, three quarters of the cases were "excellent" and the remaining were still "acceptable". In between 5 and 6 years, the 25% of the cases was"excellent" while the 75% was "acceptable". After 72 months (6 years) the first prosthesis "to remake" showed up (13.7%), while the "excellent" cases were the 13% and more than 70% of the cases was still "acceptable". Therefore, the metal-ceramic prosthesis works well, is aesthetically pleasant and biologically integrated. As regards the patient treated with zirconium-ceramic prosthesis, it has been demonstrated that during the follow-up period there were: 13 cases classified as "excellent" (52.0%), thus with classification 1a, 2a, 3a; 11 cases classified as "acceptable" (44.0%), thus with at least one "b"; 1 case "to remake" (4.0%), thus with at least one "c". All the 11 acceptable cases presented only one "b" that concerned the category "1-colour and surface" for five-times (45.5%), a small imperfection in the category "2-anatomical shape" for five times (45.5%) as well, and the category "3-marginal integrity" only in one case (9.1%). The single prosthesis to remake was a three-element bridge that after only 9 months underwent a "chipping" phenomenon, which is a core fracture that nevertheless forces the total remake of the non-re-

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Table 1 - The evaluation form approved by the CDA (California Dental Association Quality Evaluation System).

Patient:_____ Treatment date:_____

Rehabilitation type:_____ Check-up date: _____

Zirconium brand and type:_____

COLOUR				
Rating	Codex *acceptable*	*unacceptable*		
R_0	SMM		Absolutely perfect	☐
R_1			Small discrepancy in colour, shade and/or translucency	
S			Discrepancy between the restoration and the dental structure with normal range of dental colouring, shade and/or translucency	☐
T		TMM	Discrepancy between the restoration and the dental structure outside the normal range of dental colouring, shade and/or translucency	☐
V			Tooth colour, shade and/or translucency aesthetically unpleasant	☐

SURFACE				
Rating	Codex *acceptable*	*unacceptable*		
R_0			Absolutely perfect	☐
R_1			The restoration surface is smooth. No irritation of adjacent tissues	
S	SRO		The restoration surface is slightly rough and porous: it can be refined	☐
T		TPIP	Deeply porous surface: irregular grooves; it cannot be refined	☐
V		VSF	Fractured or shattered surface	☐

ANATOMICAL SHAPE				
Rating	Codex *acceptable*	*unacceptable*		
R_0			Absolutely perfect	☐
S	SUCO		The restoration is slightly under-contoured	
	SOG		The occlusal contour is not continuous with edges and grooves	
	SOH		Local reduction of occlusal height	☐
	SMR		Slightly under-contoured marginal borders	☐
	SCO		Slightly open contact	☐
	SFA		Vestibular flatness	☐
	SLG		Lingual flatness	☐
	SPX		Slightly under-contoured interproximal cervical area	☐
	SOCO		The restoration is slightly over-contoured, but the material in excess can be removed	☐
T		TUCO	The restoration is under-contoured	
		TDE, TDB	Exposed dentin or base	☐
		TOC	Incorrect occlusion	☐
		TCO	Defective contact (the auto-correction is unpleasant)	☐
		TPX	Under-contoured interproximal cervical area, possible tissue damage	☐
		TOCO	The restauration is over-contoured and it cannot be correctly fixed	☐
		TOV	Excessive margins of restoration	☐
V		VMIS	The restoration is lost	☐
		VTO	Traumatic occlusion	☐
		VPN	The restoration causes tooth pain and adjacent tissues pain	☐

MARGINAL INTEGRITY				
Rating	Codex *acceptable*	*unacceptable*		
R_0			No grooves found along the margins	☐
R_1			Probing executed without obstacles, but differences in height can be recognised	
S	SCR		Grooves can be found along the margins, but they do not extend over the dentin-enamel junction During probing an obstacle is found in a single direction	☐
	SDIS		Discolouration of the margin between restoration and dental structure	☐
T		TMD, TMB	Dentin or base exposed along the margins	☐
		TPEN	Discolouration has penetrated along the margins and is directed toward the pulp	
V		VMD	Mobile restoration	☐
		VRF	Fractured restoration	☐
		VCAR	Evident caries in continuity with restoration margin	☐
		VTF	Fractured dental structure	☐

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coverable artefact. Here after we attach the summary charts of the collected data.

Discussion

The metal-ceramic prosthesis were 28 while the zirconium-ceramic prosthesis were 25. The prosthesis were similarly distributed between the two sexes in the sample groups: 50% women and 50% men composed the metal-ceramic group; 55% men and 45% woman composed the zirconium-ceramic group. In all cases, the substructure was not subject to fractures: this feature has been known for a long time regarding the metal-ceramic prosthesis but it needed adequate clinical evidence regarding the zirconium-ceramic structures; this is one of the reasons for the increasing number of studies on the topic during the years (6-8). According to those academic studies, the zirconium structure is an excellent support also in posterior sections, even though the characteristic zirconium rigidity could represent a critical feature for occlusal load bearing. Our observations demonstrated that the prosthesis survival rate in both groups reaches the 100%, thus underlying that zirconium reliability is as excellent as metallic alloy. The metal-ceramic prosthesis showed a survival rate of 96.3% after seven years, which reaches the 100% if we consider a 6 year period; the only failed restoration concerned a treatment already seven years old. The data obtained allows us to confirm that rehabilitation with fixed metal-ceramic prosthesis displays great reliability and efficacy.

The graph in Figure 1 shows that the 96.3% of the prosthesis survived after 7 years, of which the 39.16% was classified as “acceptable”. The latter category comprehends artefacts working perfectly well and completely integrated as regards aesthetic, biology and general stomatognathic system functions. During the first three years, 100% of the prosthesis was classified as “excellent”: this percentage progressively diminishes because the category “acceptable” overcomes it, starting from the fifth year.

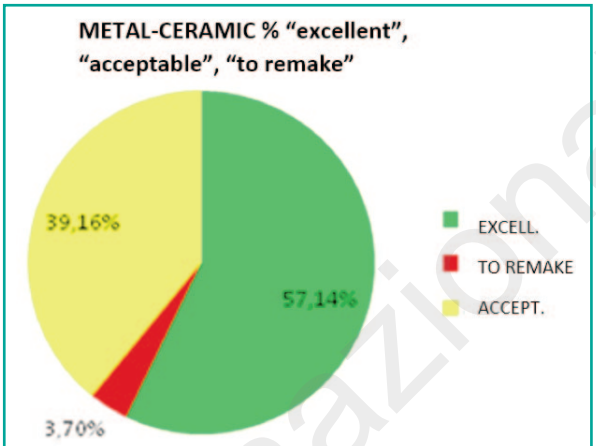

Figure 1
Metal-Ceramic prosthesis survived after 7 years.

As enlightened in the graph in Figure 2, after 6 years the 75% of the prosthesis was “acceptable” and the 25% “excellent”; after 7 years the percentages changed into 72.6% and 14.3% respectively, and the first “to remake” case appeared.

The failed metal-ceramic prosthesis was 7 years old, while the failed zirconium-ceramic prosthesis was recently made and presented non-acceptable defects regarding “colour and surface”, “anatomical shape” and “marginal integrity”.

The overall results, comprehending also the zirconium-ceramic prosthesis (Figure 3), testify a seven-year survival rate of 96%, with only a complete failure that took place before 12 months due to an extensive chipping.

The “excellent”/”acceptable” categories percentage data is slightly less favourable with respect to the metal-ceramic treated group, with a small difference of 5 percentage points (52,00% against 57.14%), which is negligible from a statistic point of view (Figure 4).

The presence of chipping phenomenon is not itself a reason for artefact rejection, but its extension and characteristics have to be taken into account. Heintze and Rousson propose three severity grades describing core fractures, on which basis it should be decided if the artefact has to be substituted or not (9). The three grades of chipping severity were:

- grade 1 if it sufficient to polish the artefact
- grade 2 if it is necessary to repair it with composite

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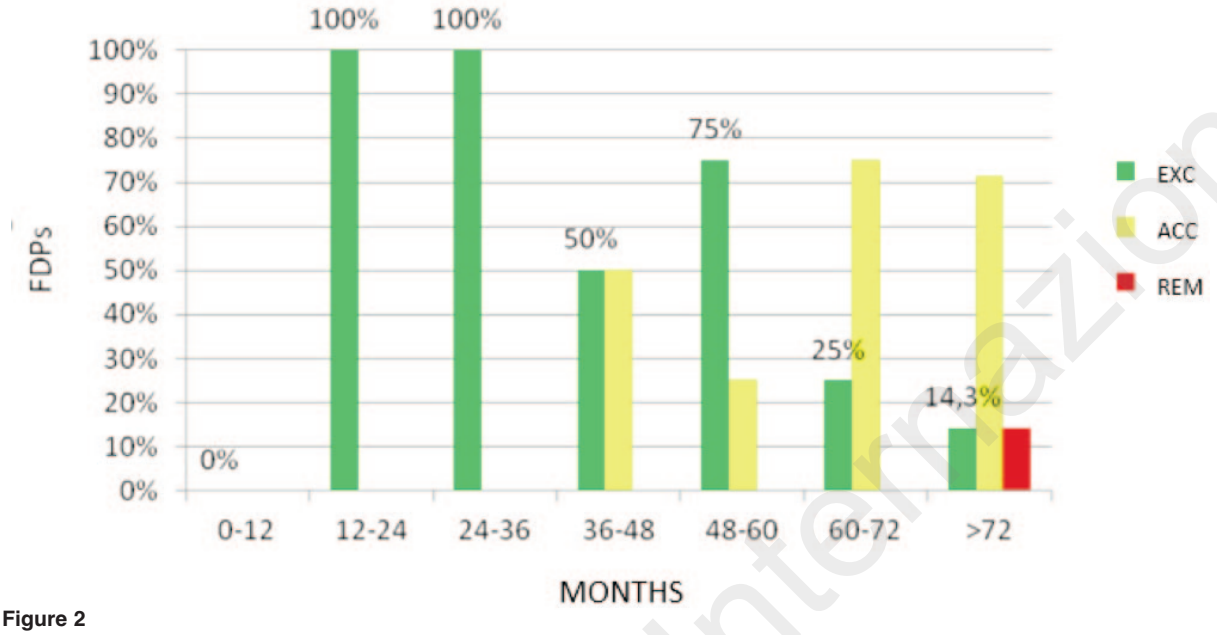

Figure 2
Metal-Ceramic CDA classification.

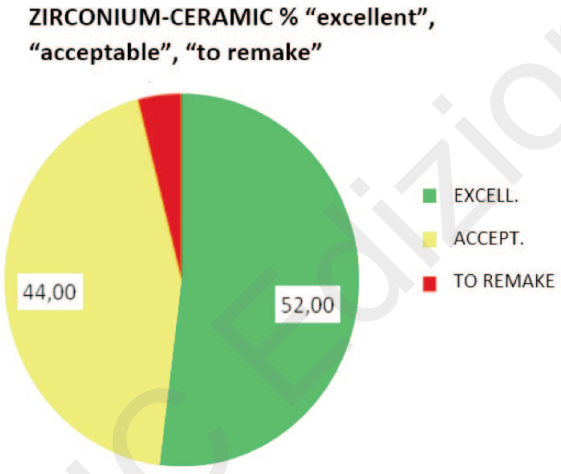

Figure 3
Zirconium-Ceramic prosthesis survived after 7 years.

- grade 3 if it is impossible to repair it.

The same Authors propose criteria for further subdivisions, which assets that the works must be classified of Grade 3 when:

- the fractured surface extends into a functional area
- the reconstruction alters the original anatomical shape in an unacceptable manner
- the reconstruction comprises a severe danger of pulpitis and excessive heat exposure
- the restoration with composite generates an evident dyschromia, aesthetically unacceptable from the patient side.

Our case belongs to grade 3 because the chipping extended to all three components of the bridge. The so premature structural failure, limited to the ceramic coating, makes us think to be caused not by an inadequate rehabilitative method, but rather by some inconvenience during the realization and/or planning procedures both in practice and in laboratory. Silvia et al. detected a zirconium-ceramic prosthesis of 6.1% percentage rate after four years and a substitution rate of 2.8% (10). Differences between the two groups can be spotted in the prosthesis classified as "acceptable". As previously noted, the frequency of the classification letter "b" was slightly different between the two groups. The graphs in Figures 5 and 6 show how the criteria for artefacts classification into the "acceptable" category are slightly more frequent for metal-ceramic products with respect to zirconium-ceramic group. In other words, the metal-ceramic pros-

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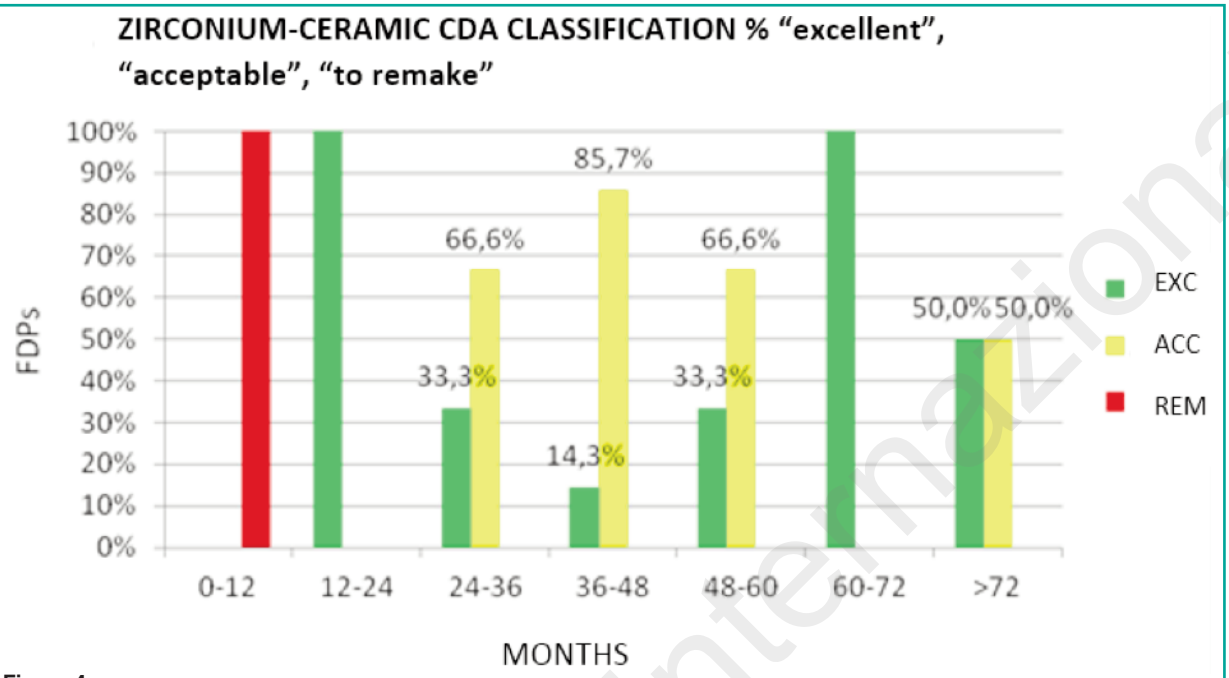

Figure 4
Zirconium-Ceramic CDA classification.

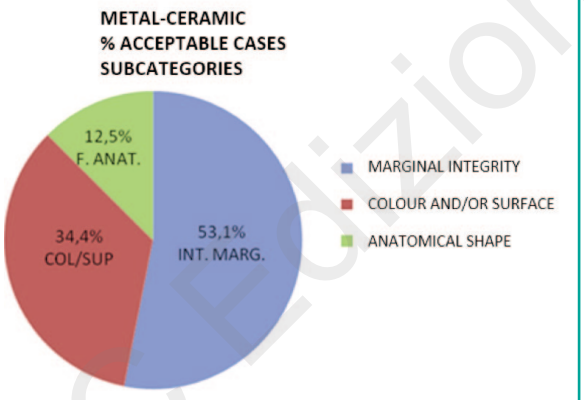

Figure 5
The criteria for Metal-Ceramic prosthesis classification into the "acceptable" category.

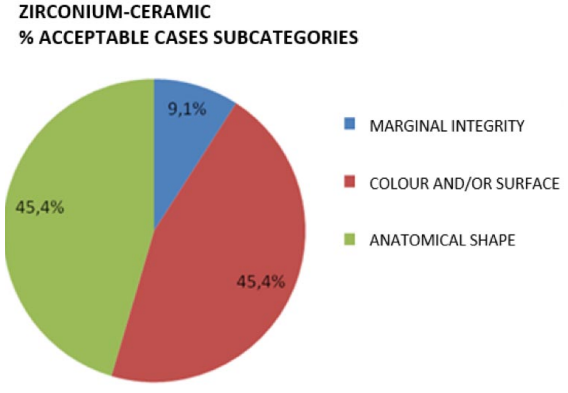

Figure 6
The criteria for Zirconium-Ceramic prosthesis classification into the "acceptable" category.

thesis suffers more the passing of the time, simultaneously accumulating modest imperfections on more features. In particular, the 10% of the cases concerns imperfections of the colour/surface, the anatomical shape and the marginal integrity; in another 10% of the cases, the imperfections affect the colour/shape and the marginal integrity; in the remaining 80% of the cases, the imperfections affect only one aspect. On the other hand, all zirconium-ceramic treated patients showed a small deficit affecting only one of the three parameters: the colours/shape, the anatomical shape or the marginal integrity. Thus, a possible improvement strategy would include more sensitive correction points for metal-ceramic prosthesis with respect to zirconium-ce-

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ramic. This means that zirconium-ceramic prosthesis score an advantage point, even though minimal. Through the graphics in Figures 5 and 6, we can notice that the totality of the artefacts belonging to the "acceptable" category has been broken down into single evaluation voices.
We can readily spot substantial differences. The prosthesis imperfection regarded the marginal integrity in the 9.1% of cases for zirconium-ceramic against the 53.1% for metal-ceramic prosthesis. As shown by the charts, in the metal-ceramic group most small defects of evaluation for marginal integrity concentrate on the older cases-in between 60 and 85 months from prosthesis delivery; all the most recent prosthesis remained unchanged at marginal level, with only one case exception. In the zirconium-ceramic group, a marginal defect is present only in one case; the remaining prosthesis does not display any minimal modification of marginal integrity. The percentages concerning colour and surface are quite similar between the two groups, although the data is slightly favourable towards the metal-ceramic group. We have to consider that "colour and surface" is a simplified index and multiple other features describe the two individual analytic categories. Since the differences between zirconium-ceramic and metal-ceramic groups are minimal as regards colour and surface category, an even deeper data analysis would be needed to distinguish in details on which aspect the two groups could possibly differ. Instead, the difference in the evaluation of altered anatomical shape is macroscopic: it resulted altered in 45.5% of zirconium-ceramic cases and in 12.5% in metal-ceramic cases.

Conclusions

The techniques and materials employed to build fixed dental prosthesis withstand continuous modifications due to the introduction of new materials and technologies, as for example with the introduction of the digital impression system or of very high precision machines, which are able to mill preformed blocks and obtain perfect 3D artefacts. The introduction of zirconium in fixed prosthesis represented an important goal; indeed, the zirconium is such a versatile material that represents a valuable substitute of metallic alloys for substructures realization even in prosthesis for posterior areas. The first certain data obtained from our study is the absence of substructure's fractures in all cases-both the 28 metal-ceramic and the 25 zirconium-ceramic prosthesis. This result was expected for the metal alloy structures, but not as much predictable for the zirconium structures, which have shown to be capable of adequately bearing the masticatory load in the posterior section, even seven years after functionalization. Both methods demonstrated a seven-year extremely high survival rate, with almost overlapping percentages of 96,3% for metal-ceramic and 96.0% for zirconium-ceramic. When taking into account the data referred to the CDA classification that subdivides the artefacts in three categories "excellent", "acceptable" and "to remake", the total distribution is again overlapping. We can easily notice it in the graphs in Figures 1 and 3, where "acceptable" percentage reaches the 39.16% for metal-ceramic and the 44.00% for zirconium-ceramic, with a mocking 4.84% difference.
In a more detailed analysis, significant differences emerged between metal-ceramic and zirconium groups over the single classification voices composing the "acceptable" category (Figures 5, 6). If we isolate from the previous graphs the "acceptable" data and break it up into the three subcategories – "colour/surface", "anatomical shape", "marginal integrity" – we can identify some peculiar statistic aspects. Shown below are reported the graph describing the previous topic.
As regards the subcategory "colour/surface", we can detect a slight advantage – the 11% – of the metal-ceramic prosthesis. The real difference lies in the two remaining subcategories-"anatomical shape" and "marginal integrity". The metal-ceramic artefacts suffer a small alteration of the margin in the 53.1% of "acceptable" cases (that is the 20.79% of the total treated cases) while their anatomical shape remains almost unaltered; our data indicates that the slight mod-

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ifications detected emerge progressively with the passage of time, determining a prosthesis aging phenomenon. For the zirconium-ceramic artefacts, the situation is specular: the "marginal integrity" is their strong point because it is minimally modified in the 9.1% of "acceptable" cases while the anatomical shape presents small alteration in the 45.4% of "acceptable" cases (that is the 19.98% of the total treated cases). The aging phenomenon that arises for metal-ceramic prosthesis is absent. A gold standard for fixed prosthesis on posterior teeth cannot yet be defined; the confronted methods, metal-ceramic and zirconium-ceramic, demonstrated to be adequate for the target rehabilitative therapy. The masticatory load is greatly tolerated by the respective substructures, which did not show any inclination to fracture. The major disadvantage of ceramic restoration is the low fracture resistance with respect to the metal-ceramic restoration, especially regarding the fixed prosthesis in the posterior region (11). Various studies demonstrated that the fixed metal-ceramic prosthesis survives 5,10 and 20 years with survival rates ranging from 95% to 89%, 90% and from 41% to 70%, respectively (12, 13); on the contrary, studies about ceramic restoration demonstrated lower survival rates (11). At the moment, the zirconium is the most resistant ceramic material available on the market and also the most stable, due to its excellent mechanical characteristics that allow it to be used for dental fixed prosthesis in posterior regions through the technique "Computer – Aided Design/ Computer – Assisted Manifacture (CAD / CAM)" (4, 14). *In vitro* and *in vivo* studies (14, 15) mark zirconium as a promising alternative to metal-ceramic in the posterior sections as well; to sustain this concept, various studies-including the last two cited- show a fracture rate ranging between the 0% and the 2.2% (6, 16). However, the zirconium is exposed as well to inconveniences and complications such as chipping (6, 17-50).

Various mid-term studies also suggest that in a close future the zirconium could represent a valid alternative to metal-ceramic.

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