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Is early implant failure a consequence of apical periimplantitis?

Biological failure of dental implants is divided into early (failure to establish osseointegration) and late (failure to maintain established osseointegration). Most of the time, early implant failure is diagnosed as a failure of osseointegration, which is the same as saying idiopathic implant failure. A deeper analysis of early failures should consider early apical periimplantitis, also known as an implant peri-apical lesion, which is an infectious-inflammatory process of the tissue surrounding the implant apex.

During the early stages of this process, the coronal bone architecture may be preserved, though progression will lead to an osseointegration failure. Early apical periimplantitis constitutes early failure, since the osseointegration process is interrupted (at least around part of the implant) and is diagnosed between 7 days and 3 months after implant placement.

Various etiological factors have been suggested, based on the potential source of contamination: implant surface contamination, overheating during drilling, pre-existing disease, immediate post-extraction placement, endodontic disease associated with the extracted tooth or adjacent teeth, pre-existing bone disease, and the presence of root remains or foreign bodies. The body of evidence is very limited, however. At present, early periimplantitis is considered to have a multifactorial origin, involving exposure to 1 or more triggering factors.

Apical periimplantitis is rarely diagnosed, so it is difficult to have a significant number of cases with previously recorded information of the state of the adjacent teeth and of the tooth being replaced, as well as information on the surgical procedure, to identify risk factors for early apical periimplantitis. There are failed osseointegration processes that have similar signs and symptoms to those of periapical implant lesions, which are a consequence of incorrect 3-D implant placement (such as flapless implant placement and fenestration of the buccal plate) or infections of biomaterials.

It is difficult to know the true dimension of this clinical condition and its total impact regarding early implant failures because there are few studies in the literature addressing it. Further knowledge of this condition will lead to its prevention and early treatment, and will reduce the number of early implant failures.

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Efficacy of a universal adhesive on the bond strength of a luting cement to leucite-reinforced glass-ceramic

Abstract

Objective

The present study compared the efficacy of a universal adhesive containing silane, bis-GMA and 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) monomer with that of silane applied alone or combined with bis-GMA or 10-MDP, but in separate steps, on the microtensile bond strength of a CAD/CAM leucite-reinforced glass-ceramic to a resin cement.

Materials and methods

Sixty-four blocks from IPS Empress CAD (Ivoclar Vivadent) were etched (5% hydrofluoric acid) and treated with:
(1) RelyX Ceramic Primer (3M ESPE; control group; group 1);
(2) RelyX Ceramic Primer + Adper Scotchbond Multi-Purpose Adhesive (group 2);
(3) Single Bond Universal Adhesive (3M ESPE; group 3);
(4) CLEARFIL PORCELAIN BOND ACTIVATOR + CLEARFIL SE BOND PRIMER (both Kuraray Noritake Dental; group 4).

The blocks were bonded in pairs with RelyX ARC (3M ESPE) and sectioned into microbars, which were submitted to microtensile testing. Microtensile bond strength data (MPa) were analyzed by 1-way ANOVA and Tukey tests (α = 0.05). Failure mode was determined under a stereomicroscope (×20).

Results

The control group, group 2 and group 4 exhibited microtensile bond strength values not statistically different from each other, but higher than those of group 3. Group 2 presented the lowest percentage of adhesive failures and the highest percentage of cohesive failures within the resin cement.

Conclusion

The universal adhesive showed the worse performance on the microtensile bond strength of a CAD/CAM leucite-reinforced glass-ceramic with a resin cement when compared with that of silane applied alone or combined with bis-GMA or 10-MDP, but in separate steps. Long-term studies investigating how these groups behave when submitted to hydrothermal aging, simulating the oral environment over time, are necessary.

Keywords

Dental bonding; adhesive; dental porcelain.
Adhesive systems and bond strength

**Introduction**

Nowadays, the increasing demand for esthetic restorations has stimulated the development of esthetic restorative materials and, concomitantly, new adhesive systems. Although zirconia and lithium disilicate ceramics have been widely used for manufacturing metal-free restorations, in the case of veneers, inlays/onlays and even anterior crowns, leucite-reinforced glass-ceramics could be an interesting option considering their esthetic potential and higher mechanical strength compared with conventional feldspathic porcelains.1

In order to achieve successful cementation, both micromechanical interlocking and chemical bonding should be present.1 For silica-based ceramics, the first bonding mechanism is successfully achieved with hydrofluoric acid (HF), which dissolves the glassy matrix surrounding the crystalline phase, creating a microretentive surface and consequently, an increased bonding area.2–4 The chemical bond between the silica of glass-ceramics (Si–O–Si formation by means of condensation reaction) and the organic groups of resin cements is achieved via silane coupling agents, more commonly methacryloxypropyl-di- methoxysilane (MPS).1, 5–7 Therefore, for bonding glass-ceramics, etching with HF followed by silane is the classical protocol.8

More recently, universal adhesives were developed with the aim of simplifying the time-consuming procedure of conditioning both the tooth and the restoration surface with etch-and-rinse adhesives, providing a single product that meets the needs of different substrates. Some of these universal adhesives (Single Bond Universal Adhesive, Scotchbond Universal, CLEARFIL Universal Bond) contain as main components silane, 10-methacryloyloxydecyl dihydrogen phosphate (10-MDP) monomer and dimethacrylate (bis-GMA), all together in a single bottle. According to the manufacturer (3M ESPE) of the Single Bond Universal Adhesive, each component was added with a specific purpose, that is, 10-MDP to provide chemical bonding to zirconia, alumina and metals; and silane to chemically bond to glass-ceramic surfaces. The application of a thin layer of resin to the previously HF-etched and silane-treated ceramic surface improves adhesive bonding by providing better wetting of the ceramic surface by the resin cement.2, 3 The bis-GMA monomer commonly present in universal adhesives can achieve this purpose, in addition to acting as a cross-linker,9 without the need for an additional step. However, the combination of all these components in a single bottle might cause some interference in their roles, either by a chemical interaction between them10, 11 or even by some competition to react with the substrate.12 In a study in which zirconia was air-abraded with silica-modified Al2O3 particles, the authors raised the possibility of having influenced competition between the silane and 10-MDP of Scotchbond Universal adhesive to interact with the ceramic surface, thus preventing each other from acting effectively.12 The chemical affinity between 10-MDP and zirconia is well established in the literature.13, 14 However, since the efficacy of 10-MDP on adhesive bonding to glass-ceramic has been insufficiently investigated, it is not known if the silane and 10-MDP would have their roles compromised when applied to the glass-ceramic in a single step.

The aim of the present study was to compare the efficacy of a universal adhesive containing silane, bis-GMA and 10-MDP with that of silane applied alone (control group) or combined with bis-GMA or 10-MDP, but in separate steps, on the microtensile bond strength (MTBS) of a CAD/CAM leucite-reinforced glass-ceramic with a resin cement. The null hypothesis was that the performance of the universal adhesive would be similar to that of the silane applied alone (control group) or combined with bis-GMA or 10-MDP, but in separate steps.

**Material and methods**

The materials used in the present study are summarized in Table 1.

**Specimen preparation**

Sixty-four ceramic blocks (IPS Empress CAD, Ivoclar Vivadent) were obtained (12 × 10 × 5 mm) using a saw (IsoMet 1000, Buehler) with a water-cooled diamond disk and were polished under wet conditions with 180, 400 and 600 grit silicon carbide abrasive papers.

One surface of each block was etched with 5% HF for 1 min, washed under tap water and dried at room temperature for 24 h. The surfaces received

1. RelyX Ceramic Primer (3M ESPE; RX; control group);
2. RelyX Ceramic Primer + Adper Scotchbond Multi-Purpose Adhesive (3M ESPE; RXASM);
3. Single Bond Universal Adhesive (SBU);
Adhesive systems and bond strength

The blocks were stored in distilled water for 48 h and were then sectioned under constant irrigation into 1.0 × 1.0 mm microbars using a saw machine and a 0.3 mm thick diamond-coated cutting disk. Each specimen consisted of 10 microbars, which were fixed to a stainless-steel attachment unit. The MTBS was tested by applying tensile load to the bonded interface in a mechanical testing machine (EMIC DL2000, EMIC Equipment and Systems Testing, São José dos Pinhais, PR, Brazil) using a 1 kN load cell at a crosshead speed of 0.5 mm/min. The fractured surfaces were examined under a stereomicroscope (M80, Leica Microsystems) at ×20 magnification by a single trained observer, and the failure mode was classified as adhesive (the complete ceramic surface was visible), mixed (both the ceramic surface and a cement layer were visible), cohesive within the resin cement (almost all of the surface was covered with resin cement) and cohesive within the ceramic (Fig. 1).

Results

Microtensile bond strength

The 1-way ANOVA (F = 10.90, P < 0.001) revealed significant differences in MTBS values between the groups. Table 3 presents the mean MTBS values, standard deviations and statistical results verified by the Tukey HSD test. The RX,
RXASM and CLESYS groups exhibited MTBS values statistically similar to each other and higher than those of the SBU group.

**Failure mode analysis**

Table 4 presents the percentage distribution of failure mode between the groups. The RXASM group exhibited the lowest percentage of adhesive failures (2.0, 2.4 and 2.7 times lower than those presented by the SBU, RX and CLESYS groups, respectively) and the highest percentage of cohesive failures within the resin cement (2.2, 2.3 and 4.3 times higher than those presented by the SBU, RX and CLESYS groups, respectively).

**Discussion**

The research hypothesis, which assumed that the performance of the universal adhesive would be similar to that of the silane applied alone (control group) or combined with bis-GMA or 10-MDP, but in separate steps, was rejected, since SBU exhibited the lowest MTBS values when compared with the other groups. In the present study, the RX, RXASM and CLESYS groups exhibited MTBS values similar to each other and higher than those of the SBU group. In the RX group, only the silane RX was applied after etching the glass-ceramic surface with HF. According to Makishi et al., the 3 silanol groups resulting from the hydrolysis of the silane RX (which contains 3-methacryloxypropyltrimethoxysilane) form covalent bridges with the hydroxyl groups of the glass-ceramic phase.9 Afterward, the organofunctional groups of the silane react with the resin monomers of the resin cement.4 The application of only a silane coupling agent (RX group) over the etched surface has been indicated for a long time as a chemical treatment to improve the bonding at the glass-ceramic/resin cement interface,15, 16 and therefore, this group was considered the control treatment in the present study.

It was expected that the use of the hydrophobic unfilled RXASM after application of the silane (RXASM group) would increase the bond strength in comparison to the RX group, keeping in mind that the resin monomers of the adhesive might improve the wetting of the glass-ceramic by the resin cement;2, 17 however, no difference in MTBS values was found between these groups.
Adhesive systems and bond strength

The similarity between the RX and RXASM groups might have been due to the already low viscosity of the RelyX ARC resin cement.\(^{18}\) If a high-viscosity resin cement had been used, the adhesive may have played a role in improving the wettability. In the study by Fabião et al. in which 2 glass-ceramics were HF-etched and silane-treated with RX, when the RXASM was used before the RelyX U100 resin cement, a significantly higher bond strength and a slight decrease in adhesive failures and increase in cohesive failures within the ceramic were observed in comparison to when this cement was used without that adhesive.\(^{17}\) These authors related this improvement to the increase in the wetting ability of the cement provided by the adhesive.\(^{17}\) Hooshmand et al. observed similar behavior regarding bond strength and failure mode after having treated the silanized leucite-reinforced ceramic surface with a thin layer of unfilled resin.\(^{7}\) The authors attributed the increase in cohesive failures within the resin cement to a reduction in the number and size of the flaws at the adhesive interface. According to them, this situation represents the best bonding condition. In the present study, despite the statistical similarity in MTBS values between the RX and RXASM groups, the RXASM group exhibited, in comparison with the RX group, a decrease in the percentage of adhesive failures (from 42.0% to 17.0%) and an increase in the percentage of cohesive failures within the resin cement (from 13.0% to 31.0%) and the ceramic (from 5.0% to 10.0%). Therefore, although no significant difference in the mean MTBS values was observed, the change in the failure mode indicates that the application of a thin layer of adhesive after the silane may provide better wetting of the glass-ceramic. The adhesive strengthened the bond of the resin cement to the ceramic surface. Besides the probable mechanical role (wetting ability) of the RXASM at this interface, its monomers co-polymerize with the methacrylate end of the silane and with the monomers of the resin cement.\(^{9}\)

The CLESYS group, which had the silane MPS (as the RX group) and the 10-MDP phosphate monomer, in separate bottles, exhibited no significant difference in MTBS values and a similar failure mode pattern with equal distribution between adhesive and mixed failures when compared with the RX group. This similarity was probably due to the chemical reaction that occurred between the silane and the hydroxyl groups of the glass-ceramic in both groups.\(^{4,9}\) Having the 10-MDP applied afterward (CLESYS group) did not contribute to improving the MTBS value. In order to compare the results of the present study with those in the literature, no studies were found that evaluated in glass-ceramics the efficacy of a silane coupling agent applied separately followed or not by an application of 10-MDP, as in the RX and CLESYS groups of the present study. In general, the silane and the 10-MDP were in the same bottle mixed with other ingredients, creating another situation.

Unlike the RX, RXASM and CLESYS groups, in which the MPS-based silane was applied in a separate step, alone (RX group) or combined with the bis-GMA monomer (RXASM group) or with 10-MDP (CLESYS group), the universal adhesive used in the SBU group had all these components in a single bottle. In order to justify the poorer performance of the SBU group in comparison with the RX, RXASM and CLESYS groups, 2 possible explanations were found in the literature:

1. In SBU, the bis-GMA monomer, by being in the same bottle as the silane, may have inhibited the chemical reaction that occurred between the silane and the hydroxyl groups of the ceramic.\(^{10,11}\)

### Table 3
MTBS mean values and standard deviations (MPa).

<table>
<thead>
<tr>
<th></th>
<th>RX</th>
<th>RXASM</th>
<th>SBU</th>
<th>CLESYS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>31.0 ± 5.4 (A)</td>
<td>30.8 ± 1.6 (A)</td>
<td>19.1 ± 5.9 (B)</td>
<td>29.1 ± 5.3 (A)</td>
</tr>
</tbody>
</table>

Different letters indicate significant differences (P < 0.05).

### Table 4
Percentage of each failure mode in the testing groups.

<table>
<thead>
<tr>
<th></th>
<th>RX</th>
<th>RXASM</th>
<th>SBU</th>
<th>CLESYS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cohesive within ceramic</td>
<td>5%</td>
<td>10%</td>
<td>2%</td>
<td>9%</td>
</tr>
<tr>
<td>Cohesive within resin cement</td>
<td>13%</td>
<td>31%</td>
<td>14%</td>
<td>7%</td>
</tr>
<tr>
<td>Mixed</td>
<td>40%</td>
<td>42%</td>
<td>49%</td>
<td>36%</td>
</tr>
<tr>
<td>Adhesive</td>
<td>42%</td>
<td>17%</td>
<td>35%</td>
<td>48%</td>
</tr>
</tbody>
</table>

RX = RelyX Ceramic Primer (control group); RXASM = RelyX Ceramic Primer + Adper Scotchbond Multi-Purpose Adhesive; SBU = Single Bond Universal Adhesive; CLESYS = CLEARFIL PORCELAIN BOND ACTIVATOR + CLEARFIL SE BOND PRIMER.
The low pH (2.7) of the tested universal adhesive may have promoted premature silane hydrolysis followed by dehydration condensation, resulting in the formation of oligomers that cannot bond to glass. Yoshihara et al. did not detect silanol in the Scotchbond Universal adhesive (same composition as SBU), although the manufacturer states the presence of silane in its composition. Some authors have recommended using a separate silane primer to achieve enough silane-coupling effect on glass-ceramics. Both explanations cited here justify the insufficient effectiveness of the silane incorporated in SBU.

In the RXASM group, silane and adhesive containing bis-GMA were applied separately, allowing the silane to react with the glass-ceramic. When the failure mode of the RXASM and SBU groups was compared, the percentage of adhesive failures of the SBU group was twice that of the RXASM group (35% against 17%). Some studies have also demonstrated superiority of the combination of RX and RXASM over SBU and Scotchbond Universal adhesive, exhibit similar formulations. When the SBU and CLESYS groups were compared, although both adhesives had silane and 10-MDP adhesive monomers, CLESYS does not contain bis-GMA and, unlike SBU, comes in 2 bottles, 1 (CLEARFIL PORCELAIN BOND ACTIVATOR) containing the silane MPS (applied in a separate step) and the other (CLEARFIL SE BOND PRIMER) the 10-MDP adhesive monomer.

Therefore, in the SBU group, the mean MTBS value probably resulted from the mechanical interlocking provided by the HF etching added or not to an eventual chemical reaction between the MDP monomer and the glass-ceramic components that, if it occurred, was presumably weaker than that between the silane and the glassy matrix. During the development of the present study, a group HF-etched and treated only with CLEARFIL SE BOND PRIMER (which contains only 10-MDP) was also tested under the same conditions as those of the other 4 groups (although it was not included in the study), achieving a mean MTBS value of 21.5 MPa, which is very close to that found for the SBU group (19.1 MPa). Kim et al., evaluating the performance of universal adhesives on the microshear bond strength to leucite-reinforced ceramic, found no significance difference between SBU and All-Bond Universal, which contains basically the MDP adhesive monomer, similar to CLEARFIL SE BOND PRIMER. Studies that elucidate the chemical interaction between the 10-MDP monomer and glass-ceramic are crucial to prove or disprove this assumption.

**Conclusion**

The present study indicated that SBU, which contains silane, bis-GMA and 10-MDP in a single bottle, showed the worst performance when compared with that of silane applied alone or combined with bis-GMA or with 10-MDP, but in separate steps, on the MTBS of a CAD/CAM leucite-reinforced glass-ceramic with a resin cement. However, the long-term durability of the groups was not evaluated and is crucial to determine their effectiveness. Studies that investigate how these groups behave when submitted to hydrothermal aging, simulating the oral environment over time, are necessary.

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**Competing interests**

The authors declare that they have no competing interests.
References


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Abstract

Objective

The objective of this article was to describe the relationship between the movement of the interincisive point and the working temporomandibular joint condyle with regard to the horizontal plane during laterality movements.

Materials and methods

Clinical records of patients complaining of temporomandibular joint disorder for whom axiographic examination had been performed were searched and analyzed retrospectively at a private practice. Only patients showing an asymmetrical gothic arch with retrusive lateral excursion in an absolute sense with respect to the frontal plane or with respect to the contralateral laterality were selected.

Results

Sixty-six clinical records of patients who had undergone axiographic examination were found. A total of 37 patients met the inclusion criteria and were included in the study. In 81.08% of the analyzed cases, there was posterior movement of the working condyle on the side in which the interincisive point showed greater retrusive laterality excursion.

Conclusion

During lateral excursion of the masticatory cycle, the balancing condyle moves in an anteromedial direction. The working condyle rotates on its axis and moves laterally. A steep lateral excursion on the frontal plane corresponds to a retrusive horizontal masticatory functional angle on the horizontal plane; a retrusive Planas functional masticatory angle tends to induce retraction of the corresponding working condyle. Retrusion of the working condyle during the masticatory cycle may induce a force that compresses the delicate retrodisclal tissue. The clinical effect of this repeated force on the retrodisclal tissue still has to be investigated.

Keywords

Gothic arch; Bonwill triangle; alternating unilateral mastication; retrusive laterality; condylar retraction; horizontal masticatory functional angle; Planas functional masticatory angle; kinesiology; axiography.
Background

When in the course of phylogeny the dental structures appeared, their function was not that of mastication. In almost all nonmammalian vertebrates, the primary function of teeth is to channel food into the digestive system; only mammals find it extremely necessary to reduce it to pieces. The current dental morphology of humans is the result of evolution begun with mammals about 220 million years ago: from the initial form of a simple cone to a progressive and more diversified complex of cusps, pits and ridges. The tooth has also evolved in response to changes in the environment.\(^1\)

For instance, reptiles have always used their teeth only to grasp and inactivate their prey; the food cannot be held in the mouth for chewing, but must be quickly swallowed after it has been inserted in the oral cavity\(^2, 3\). Mastication is one of the most distinctive features of mammals\(^4\); only with their appearance in vertebrates did teeth fully acquire their specific grinding function with the characteristic alternate unilateral mastication. In mammals, owing to the large amount of energy required to maintain a constant body temperature, there was need for a greater catabolic efficiency of the alimentary canal with respect to reptiles, also through a more efficient masticatory system\(^5\). The crushing of food obtained by chewing increased the efficiency of energy assimilation from food, supporting the high metabolic rate required by endothermic mammals\(^6\).

Since the appearance of primitive mammals, only 1 side of the dentition has been used during mastication\(^7\). In fact, the main feature is unilateral alternate mastication. From this scheme, new ones have developed, decreasing (carnivores) or increasing (herbivores) the asymmetrical movement of the jaw\(^8\)–\(^11\); simultaneous bilateral chewing is rare.\(^12\) Single-sided mastication allows finer control and better precision of the chewing movements, generating more efficient forces with the recruitment of both the working and the balancing muscles; the better control of movements increases the effectiveness in the crushing of food, even if of very variable consistency. The alternation of the masticatory side allows the best distribution of the stresses of the dental, periodontal, bone, muscular and articular structures, allowing a dissipation of the masticatory forces.

Since alternating unilateral mastication implies the realization of masticatory cycles on each single hemi-arch, these must be carried out with the same ease and efficiency on both sides. Planas has described the Planas functional masticatory angle (PFMA) as a regulator of that phase of the masticatory cycle in which the occlusal surfaces begin to interface functionally\(^13\).

Mainly unilateral mastication represents an adaptation that does not reflect our chewing physiology. Returning chewing to take place on both sides tends to recover the correct physiology of masticatory alternation. A previous study of the authors of the present work related the trajectory of the interincisive point in the lateral excursion carried out on the frontal plane to the one carried out by the same point on the horizontal plane (horizontal masticatory functional angle, HMFA)\(^14\). To give continuity to the previous study, the aim of this study was to describe the relationship between the movement of the interincisive point and the working temporomandibular joint (TMJ) condyle with regard to the horizontal plane during lateral excursion.

Materials and methods

Inclusion criteria

Clinical records of patients complaining of TMJ disorder for whom axiographic examination had been performed were searched and retrospectively analyzed at a private practice. Only patients showing an asymmetrical gothic arch with retrusive laterality in an absolute sense with respect to the frontal plane were included in the study group.

Clinical procedures

The clinical examination was performed by the same expert operator with more than 10 years of experience in the gnathology field using a 3-D JMA system axiograph (zebris Medical) that analyzed the tracings made by the condylar points during lateral excursion of the incisal point. This device consists of an ultrasonic source attached to the labial surface of the mandible by means of a customized accessory and a sensor system housed in another accessory, mounted around the head of the patient in the form of a facial arch. The operator sets a plane by means of the coordinates of the two condylar points and an infraorbital point. The system records the movements of at least 3 points...
Axiographic study of condylar retrusion

Sixty-six clinical records of patients who had undergone axiographic examination were found and analyzed retrospectively. A total of 37 patients (25 females and 12 males) met the inclusion criteria and were included in the study. All of the patients showed TMJ symptoms and signs like clicking, pain during mastication, and limited movement and opening of the jaw.

All of the axiographic tracings studied showed an asymmetrical gothic arch with retrusive laterality in an absolute sense with respect to the frontal plane or with respect to the contralateral laterality. Thirty-seven axiographic tracings of laterality in 37 patients were studied.

The values of the terminal points of the interincisive lateral trajectories were compared on both sides with the values of the terminal points of the trajectories of the corresponding working condyles. In 81.08% of the cases, there was posteriorization of the working condyle on the side in which the interincisive point showed more retrusive laterality.

Discussion

This study was based on the analysis of lateral excursion, taking into consideration two gnathological concepts:

1. The Bonwill triangle described in 1858 as an equilateral triangle placed on the horizontal plane, with the 3 vertices placed at the interincisive point of the jaw and in the middle of the two condyles. The sides of this triangle are 10 cm, although the correctness of this measurement has been questioned.15
Fig. 3

Asymmetrical gothic arch.

(2) The gothic arch that Gysi in 1930 first described with his recordings is a polygon created by the interincisive point on the horizontal plane with lateral and extreme protrusive movements.16

Keeping these two concepts in mind, in the present study, it was attempted to understand the relationship during lateral excursion on the horizontal plane between the shape of the gothic arch generated by the interincisive point (I) and the displacement of the vertex of the Bonwill triangle corresponding to the working condyle (C; Fig. 1). Although this may seem a very theoretical and abstract topic, the assessment of these relationships is important for the diagnosis and therapy of dysfunctional patients. In classical gnathology, the tracings of laterality on the horizontal plane are represented in a very regular and symmetrical way: a symmetrical frontal and lateral shift on both sides (Fig. 2). In kinesiographic tracings of dysfunctional patients, a deformation of the gothic arch is almost always observed, in which 1 or both tracings of laterality tend to lose the anterolateral direction, in order to acquire a tendency toward posteriority (Fig. 3).

The gothic arch can be interpreted as a section on the horizontal plane of the volume identified by Posselt in his diagrams. This volume, formed by the extreme movements of lateral and protrusive opening, delimits the dynamic freedom that the jaw can express, during the functional movements that occur essentially within this perimeter.17 A large and symmetrical volume indicates a wide and symmetrical freedom of movement of the muscular structures of the jaw and of a physiological range of movement of the TMJ, essential in physiological alternating unilateral mastication (Fig. 4).

In 1984, Mongini put in geometrical relation the interincisive point with the condyles on the horizontal plane and in the static position of maximum intercuspation, statically describing the relations.18 With the kinesiographic layout of the laterality on the horizontal plane (gothic arch), the movement of the interincisive point can be kinematically put in relation to the movement effected by the working condyle: (1) If point B (balancing condyle) always moves in an anteromedial direction. (2) If point L (working condyle) has an anterolateral or posterolateral progression, then (3) point I will have the same trend of movement as point L (Fig. 5).

In a previous study, a relationship was established between the trajectories of the movement of the interincisive point on the frontal plane (PFMA) with those described by the same point on the horizontal plane (HMFA), highlighting that the steeper laterality on the frontal plane tends to be retrusive on the horizontal plane.14 In the present study, it was attempted to outline how the tracing of retrusive laterality of the interincisive point tends to correspond to posterior displacement of the apex of the Bonwill triangle of the working condyle.

The posteriorization of the condyle from its physiological position in the mandibular fossa, tends to create a compression of the soft retrodiscal tissue against the posterior wall of the mandibular fossa. The bilaminar zone of the retrodiscal tissue, being rich in vessels, nerve endings, adipose tissue and elastic fibers, is histologically unsuitable to support compressive
**Axiographic study of condylar retrusion**

**Fig. 4**
Different shape and size Posselt volume.

**Fig. 5**
Relationship between the interincisive point and working condyle.

**Fig. 6**
Relationship between the movement of the interincisive point and retrusion of the working condyle.
Axiographic study of condylar retrusion

forces. When subjected to repeated traumatic compressions, this soft structure reacts with inflammation that might result in fibrotic tissue composed of loose connective tissue,\(^\text{19-20}\) with a significant increase in fibroblast density, the presence of restricted and obliterated artery lumina and a significantly lower distribution of elastic fibers.\(^\text{21}\)

During the phase of the power stroke in the crushing of the bolus, a functional moment in which the most intense forces of mastication develop, condylar retrusion tends to make the mastication traumatic, and this tends to induce mastication on the opposite side. In all of the tracings of laterality with retrusion of the interincisive point, there was a tendency to condylar retrusion. If in the lateral excursion the interincisive point presents an absolute retrusive trajectory, or relative to the contralateral movement, the corresponding working condyle tends to show a tendency to retrusion.

It must be remembered that in retrusive laterality of the interincisive point, condylar retrusion cannot be determined in a strictly geometric way. In fact, the posteriorization of the condyle will be influenced by other factors and will appear to be (1) directly proportional to both the posteriorization of the laterality tracing and its extension (Fig. 6), or (2) inversely proportional to the verticality of the movement of the interincisive point on the frontal plane. The lateral excursion is expressed on the 3 planes of the space, and the vertical component tends to exhaust the retrusive thrust of the working condyle (Fig. 7).

A steep PFMA on the frontal plane tends to correspond to a retrusive HMFA on the horizontal plane; a retrusive HMFA tends to induce

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Fig. 7
The retrusive thrust is attenuated by the vertical component of the lateral excursion.
Axiographic study of condylar retrusion

retrusion of the corresponding working condyle. The lateral tracings, essentially overlapping the guidance of the entry phase of the masticatory cycle, are indexes of masticatory function of that side, being important proprioceptive parameters on which both masticatory cycles and their physiological alternation are set. Occlusal interference inducing retrusive laterality during mastication, that is, retrusion of the entry phase of the potentially compressive masticatory cycle of the delicate retrodiscal tissue, will make the system tend toward prevalent mastication on the opposite side.

The elimination of this interference by removing the functional obstacle through an accurate occlusal check will tend to favor a physiologically alternating mastication, resulting in symmetrization and enlargement of the gothic arch and with it of the entire Posselt volume, an indication of a better expression of muscular and articular function (Fig. 8).

The retrospective nature of the present study is the main limitation of the present report.

Competing interests

The present study was self-funded by the authors and their institutions. There is thus no conflict of interest to be declared.
References


A preliminary study of the effect of room temperature incubation on phylogenetic composition of salivary microbiota

Abstract

Objective

Human oral microbiome research has revealed that differences in microbial communities may lead to not only oral disease but also systemic conditions. Although large-scale cohort studies are needed to further investigate these relationships, little is known about the storage method of salivary samples collected in the clinical field. In this study, the temporal stability of salivary microbiota at room temperature was investigated to support future cohort studies of the oral microbiome.

Materials and methods

Three salivary samples collected from 2 healthy adults were incubated at 20°C for 3 or 6 h, and the bacterial composition was then analyzed using next-generation sequencing of the 16S ribosomal RNA gene.

Results

Although slight changes in the microbial profiles were observed in the samples incubated for 6 h, principal coordinate analysis revealed significant clustering based on the origin of the salivary samples. In contrast, several increased or decreased operational taxonomic units were also detected under this storage condition.

Conclusion

Within the limitation of the sample size in this preliminary study, it can be stated that room temperature storage of salivary samples for a few hours may not affect the overall microbiota structure, while there are some changes in specific bacterial taxa.

Keywords

Salivary microbiota; room temperature storage; next-generation sequencing.
**Introduction**

Many bacteria indigenously inhabit the human body surface and digestive tract and maintain symbiotic relationships with humans. For example, in the intestine, in which the largest number of indigenous bacteria is present, there are about 38 trillion bacteria, comprised of at least 160 species that maintain a symbiotic balance. It has been suggested that an abnormal composition ratio (dysbiosis) of these intestinal bacteria is associated with obesity, type 2 diabetes, autism and allergic disease, in addition to the induction of inflammatory disease.

The oral cavity is also a niche for indigenous bacterial inhabitation, in which 5–10 billion indigenous bacteria, comprised of about 200 species, are present in adults, and the species and ratio of bacteria constituting it markedly vary among individuals, similar to intestinal indigenous bacteria. In addition, some oral flora--constituting bacteria have been determined to be not only involved in oral diseases, such as dental caries, periodontal disease and periimplantitis, but also closely affecting the systemic health state, such as the blood pressure, in addition to health of the oral cavity.

Marked progression of the nucleotide sequencing technique has markedly contributed to the recent, rapid accumulation of knowledge concerning the relationship between bacterial floras and the state of health described. The previous mainstream of sequencing, the Sanger method, takes time and is labor- and cost-intensive for analysis, and the resolution of the obtained data is not very high. Several next-generation sequencers have recently been developed and enabled the acquisition of an enormous amount of base sequence information within a relatively short time, facilitating relatively simple identification of the constitution of oral bacteria at a high analytical resolution, which was previously difficult. Large-scale analysis of oral floras and the development of test and treatment methods targeting oral bacteria are expected, but the procedures have not yet been standardized in some steps because these are novel analytical methods. Firstly, the method to extract DNA from oral samples has not been standardized. This is one of the most important steps of flora analysis using a next-generation sequencer, and biases in the flora data depending on the extraction method used have been reported. To solve this problem, it is essential to employ the same DNA extraction method when comparing samples of flora. Another step that has not been standardized is the method to store collected samples, for which less is known. When it is not possible to extract nucleic acid immediately after sample collection, freezing of the sample at −80°C or lower is the optimal storage method, but sample storage by rapid freezing is not always possible at clinical sites and in cohort studies. Several effective methods other than deep-freezing, such as the addition of ethanol to samples, have been investigated in the research field of intestinal flora, but to our knowledge, no study has been reported for oral samples other than an experiment on storage for several days using a special medium.

The aim of the present study was to analyze and evaluate changes in floras in oral samples during storage at room temperature for several hours, aiming at securing the reliability of data collected in clinical and cohort studies on the oral flora, which are expected to be frequently performed in the future.

**Materials and methods**

Salivary sample collection and storage conditions

In order to investigate the storage reliability of salivary samples at room temperature, fresh saliva was incubated at 20°C, and the temporal stability of microbiota composition was monitored for 3 or 6 h. Two samples were collected from the same subject 1 week apart. In our preliminary study, in total 3 salivary samples prepared from 2 healthy individuals were used. DNA from 9 salivary aliquots was successfully extracted, amplified and sequenced.

The study protocol was approved by the Osaka Dental University Medical Ethics Committee (approval No. 110854), and the 2 subjects signed informed consent forms.

The inclusion criterion was age > 20 years. Exclusion criteria were as follows: self-reported presence of periodontitis or dental caries, current daily smoking, and treatment with local or systemic antibiotics within the past 3 months prior to participation. The primary outcome was within-sample change in salivary microbiota composition (assessed by principal coordinate analysis) during storage at room temperature for several hours.
Subjects refrained from eating and drinking for at least 1 h before saliva collection. Three milliliters of saliva was collected in sterile plastic tubes and then homogenized by repetitive pipetting through a narrow bone tip. Aliquots (0.5 mL) of samples were dispensed into 3 sterile tubes, and 1 aliquot was then immediately centrifuged at 10,000 × g for 5 min. The remaining 2 aliquots were incubated at 20°C for 3 and 6 h, respectively, before centrifugation. Next, the supernatant was discarded, and the pellet was stored at -20°C. DNA extraction was carried out within 1 week.

**DNA extraction from salivary samples**

Bacterial DNA was extracted from 9 salivary samples via chemical and mechanical lysis using a QIAamp UCP Pathogen Mini Kit (Qiagen). The thawed pellets were immediately suspended in 500 μL of ATL buffer containing optional DX reagent, transferred to a Pathogen Lysis Tube S (Qiagen), and then homogenized with Mixer Mill MM 301 (Retsch) for 3 min at a vibrational frequency of 30 Hz. The manufacturer’s protocol was followed thereafter to complete the DNA purification, and DNA was eluted with 50 μL of AVE buffer. After recovery, DNA was also quantified using a Quantus fluorometer (Promega) and a Qubit dsDNA HS Assay Kit (Life Technologies), and stored at -80°C until use. Data collectors were blinded to subject identification.

**Library construction and Illumina MiSeq sequencing**

Bacterial 16S ribosomal DNA amplification and library construction were performed according to the 16S Metagenomic Sequencing Library Preparation guide supplied by Illumina (part No. 15044223_B). Briefly, the V3–V4 region of the 16S ribosomal RNA gene was amplified via polymerase chain reaction (PCR) using 341f/806r primers and Premix Ex Taq polymerase (Takara Bio). The PCR amplicons were purified using AMPure XP beads (Beckman Coulter). Sequencing adapters containing 8 bp indices were incorporated into the 3’ and 5’ ends of the purified amplicons by PCR. The PCR amplicons were again purified with AMPure XP beads and quantified using a Quantus fluorometer and a Qubit dsDNA HS Assay Kit (Life Technologies). After pooling equimolar amounts of amplicons, 5% equimolar of PhiX DNA (Illumina) was added, and the final library was paired-end sequenced at 2 × 250 bp using a MiSeq Reagent Kit v2 on the Illumina MiSeq platform. Sequencing was performed at the Oral Microbiome Center in Takamatsu, Japan.

**Data analysis**

The sequences were analyzed with CLC Workbench software (Version 10.0.1, Filgen) equipped with the Microbial Genomics Module plugin (Version 2.0, Filgen). Quality and chimera cross-over filtering were performed using default parameters. Operational taxonomic unit (OTU) clustering and taxonomic assignment were carried out using the Human Oral Microbiome Database (Version 14.51) as reference (clustered at 97%). Low-abundance OTUs were discarded from further analyses (less than 10 reads, less than 0.01% relative abundance). Alpha diversity was calculated using the number of OTUs. Principal coordinate analysis (PCoA) was performed on the weighted UniFrac matrix, as indicated by the significance of clustering determined by PERMANOVA with 9,999 permutations. PCoA plots were generated by the R package (Version 3.4.4).
Results

Microbiota analysis of salivary samples

The Illumina MiSeq was performed using 9 independent samples to generate a total of 791,888 raw sequence reads (Table 1). After passing the quality filter, the number of mapped sequence reads ranged from 45,973 to 55,908 (mean ± standard error of the mean of 50,019 ± 1,160; Table 1).

Stability of the microbiota at room temperature

Figures 1 and 2 present the top 10 bacterial groups at the genus and species levels, respectively. The results of all samples revealed that the top 10 bacterial genera constitute approximately 80–90% of each sample. The most predominant members of the community belonged to the bacterial genus Neisseria in volunteer A (20–35%) and Prevotella in volunteer B (25–30%). In addition, Haemophilus, Porphyromonas and Fusobacterium were detected predominantly in volunteer A, whereas TM7 [G-1] was more predominant in volunteer B. The proportion of genus Rothia varied between sampling times in volunteer A. Although the composition of the top 10 bacterial genera was slightly fractured in all lineages for 6 h, the relative changes in each were within approximately 5%. No apparent time-dependent change in microbiota was detected in the top 10 bacterial OTUs.

Effects of room temperature storage on microbial beta diversity

Results from rarefaction curves indicated that a sufficient number of reads was obtained for 16S rRNA analyses (Fig. 3). The PCoA plot based on the weighted UniFrac (beta diversity) metric revealed that the 9 samples clustered into 3 groups corresponding to each lineage (Fig. 4), and the difference was confirmed statistically by PERMANOVA ($P < 0.01$). In addition, the 2 lineage groups collected from volunteer A closely opposed each other on the PCoA plot. These results demonstrated that no overall change in community composition was observed in this experimental condition (20°C, 6 h).

Change in salivary microbiota at the OTU levels

Bacterial shifts in salivary microbiota at the OTU levels associated with incubation at room temperature (20°C) were investigated and visualized as heat maps (Fig. 5). In sample 1 of volunteer A, 2 types of Porphyromonas pasteurii were regarded as having increased OTUs at a 0.5 cutoff over the

3.3.3; R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/).
Room temperature storage of salivary microbiota

course of 6 h. In contrast, *Granulicatella adiacens*, *Streptococcus sanguinis* and *Streptococcus* sp. oral taxon 057 were decreased in the same sample. In sample 2 of volunteer A, although no OTUs were observed to have increased, *Granulicatella adiacens* and *Selenomonas* sp. were decreased. In the sample from volunteer B, *Actinomyces graevenitzii*, *Prevotella* sp. and *Porphyromonas pasteri* were increased, and *Atopobium parvulum*, *Megasphaera micronu- formis* and *Selenomonas* sp. were decreased. These results suggest that there are changes in specific bacterial taxa during room temperature storage for a few hours.

**Discussion**

The relationship between the indigenous bacterial flora and human health has been attracting attention, and several large-scale cohort studies are being performed, in which the duration and method of sample storage from sample collection to analysis is an issue. For fecal and vaginal microorganism-derived samples, several studies evaluating the degree of storage-induced changes in the flora have been performed, but no study evaluating the influence of storage conditions on oral samples has been performed. A study comparing media for oral sample storage has been reported, but it only investigated the influence of room temperature storage for several days, and to our knowledge, no study has investigated changes over a several-hour period. In the present study, we investigated the storage conditions after salivary sample collection, aiming at securing the reliability of data collected in clinical and cohort studies on the oral flora, which are expected to be frequently performed in the future.

Regarding the study design, collected saliva was kept at around room temperature (20°C) for a specified time and changes in the bacterial flora in the sample were analyzed in DNA extracted from the sample after 3 and 6 h. More than 70,000 reads could be obtained from all 9 samples collected, and at least 45,000 reads passed through the filter. This number of reads is sufficient compared with those in other analyses.

When time course changes in the flora were subjected to PCoA, slight changes within each sample were noted under the conditions of this study, but the characteristics of the floras observed at the time of sampling did not markedly change (Fig. 4). In the salivary samples collected with a 1-week interval from the same subject, the composition of the flora was similar, but the ratios appeared to have changed (Figs. 1 & 2). Regarding the individual OTU in recent analyses, it has been clarified that several specific OTUs markedly changed when the samples were stored at room temperature. When changes were closely investigated by OTU, *Porphyromonas pasteri* increased in 2 of the 3 samples, whereas *Selenomonas* sp. oral taxon 136 and *Granulicatella adiacens* decreased (Fig. 5), showing that OTUs termed “bloom,” which alter during storage at room temperature, are very likely to be present in oral samples, similar to fecal samples. It is desirable to freeze samples as soon as possible when they are
collected from the oral cavity of patients with periodontal disease and periimplantitis lesions in cohort and clinical sites. It is also important to know the species of OTUs that change during storage at room temperature to prepare for conditions in which such storage is difficult, in order to maintain the resolution of flora analysis data.

This is a preliminary study and there are some limitations. First, the sample size was small. A large number of patients may be more likely to elucidate the temporal stability of salivary microbiota. Second, the observation was based on experimentation at only 1 temperature (20°C). Addressing these limitations in future studies will be important.

Conclusion

Within the limitation of the sample size in this preliminary study, it can be stated that room temperature storage of salivary samples for a few hours may not affect the overall microbiota structure, while there are some changes in specific bacterial taxa.

Acknowledgments

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Competing interests

The authors declare that they have no competing interests.

Figs. 5A–C

Heat maps of the fold changes from 0 to 3 or 0 to 6 h in sample series 1 (A), 2 (B) and 3 (C). The heat maps illustrate the microbes with the highest relative abundance (>0.5% with respect to the total number of sequences) using a binary logarithmic color scale.
Room temperature storage of salivary microbiota

References


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A surgical approach to the management of periapical implant lesions: A report of 3 clinical cases with up to 6 years of follow-up

Abstract

Background

Periapical implant lesions may be a cause of early failure of implants. The purpose of this article is to describe the surgical treatment of the periapical implant lesion and its intraoperative approach.

Case presentations

Three patients with periapical implant lesions (2 in the maxilla and 1 in the mandible) after implant placement are described. All 3 patients reported inflammation and pain. Periapical and panoramic radiographic examination showed periapical radiolucency around the 3 implants. The diagnosis was acute suppurative stage in all 3 cases. After surgical treatment, all of the implants survived. Clinical and radiographic controls showed signs of health with a follow-up of 3, 6 and 4 years, respectively.

Conclusion

In the patients studied, pain in the area after implant placement suggested a periapical implant lesion. The surgical approach used to remove the granulation tissue showed good results. Up to 6-year clinical and radiographic controls, all 3 cases showed complete healing of soft and hard tissue. Diagnosis and early treatment are crucial to ensure a correct osseointegration process and avoid implant failure.

Keywords

Surgical procedures; operative; periapical implant lesion; implant lesion; early apical periimplantitis; early failure.
Background

A periapical implant lesion may be a cause of implant failure. This lesion, also referred to as apical periimplantitis or retrograde periimplantitis, was described by McAllister in 1992 as injuries in the apical portion of implants. A year later, Sussman and Moss defined the lesion as an infectious-inflammatory process of the tissue surrounding the implant apex. In a recent consensus, it was agreed to define it as a lesion of inflammatory and infectious nature, developing in the axial axis of the implant during osseointegration, with the maintenance of normal coronal bone in early stages.

The frequency described in the literature of this lesion is low, between 0.26% and 2.70%. Zhou et al. found an increase of up to 7.8% in frequency with the presence of an endodontically treated adjacent tooth. Several factors have been proposed that could be related to the onset of this lesion: endodontic pathology of the tooth replaced by the implant or of the adjacent tooth; pre-existing bone disease or the presence of root fragments or foreign bodies; contamination of the implant surface, and bone overheating during milling or overmilling.

Diagnosis of the periapical implant lesion involves clinical and radiographic evaluations, and the treatment will vary according to the findings:

a) If the implant has a radiolucent area (not present after surgery owing to overdrilling and manifesting over time) without pain, monitoring of the lesion is recommended, without medical treatment.

b) If the radiolucency has increased in size or if the patient develops pain, medical and surgical treatment is indicated.

Antibiotics (amoxicillin, amoxicillin/clavulanate, metronidazole and clindamycin) have been used in medical treatment, although it has been described that initial treatment with antibiotics is not effective in controlling symptomatic or active lesions, and requires surgical access.

There is no established gold standard treatment, so the goal is to eliminate the area of infection. Surgical treatment consists of infiltrative anesthesia, incision, full-thickness flap, ostectomy, apical curettage of granulation tissue and profuse irrigation. This paper describes the surgical approach in 3 clinical cases of periapical implant lesions.

Case presentations

All of the cases were diagnosed and treated in the Oral Surgery Department, Faculty of Medicine and Dentistry, University of Valencia, Valencia, Spain. All of the patients were informed about the study design and procedures. Prior to participating, they were requested to sign an informed consent document.

The classification proposed by Peñarrocha-Diago et al. was used to diagnose the stage of early periimplantitis as nonsuppurative phase, suppurative phase or subacute phase.

Surgical procedures

The same surgical procedure was carried out in the 3 cases presented. After infiltrative locoregional anesthesia and submarginal incision, a full-thickness flap was elevated, and ostectomy was carried out using a round 0.27 mm tungsten carbide bur (JOTA) mounted in a handpiece under abundant irrigation. Surgical curettage of the cavity and the implant surface was performed with an ultrasonic device (Piezon Master 700, E.M.S. Electro Medical Systems) and curettes (Double Gracey Mini Anterior/Posterior, American Eagle Instruments), under profuse irrigation with a sterile saline solution to remove any remaining contaminated tissue. The apical portion of the implant and the surrounding bone were inspected using a rigid endoscope (MÖLLER-WEDEL).

When the adjacent tooth showed an apical lesion, root canal therapy or periapical surgery, if the tooth had been endodontically treated, was performed. Before closure, if the marginal defect was wide, a collagen membrane was placed in order to avoid soft-tissue infiltration in the apex of the implant and improve new bone formation in the cavity. Tension-free soft-tissue flap closure was performed with a 6-0 polyamide suture (SERALON, SERAG-WIESSNER). Sutures were removed after 1 week.

In all cases, the following medications was prescribed: 2 g amoxicillin and a 0.12% chlorhexidine and 0.05% cetylpyridinium chloride rinse (CPC; Perio-Aid, Dentaid) for 1 min before anesthetizing the patient. Postoperatively, all 3 patients were prescribed 500 mg of amoxicillin and 250 mg of metronidazole every 8 h for 7 days, 25 mg dexketoprofen as required, and a 0.12% chlorhexidine and 0.05% CPC rinse twice daily for 10 days.
Surgical approach for periapical implant lesions

Case 1

The 48-year-old female patient, who was allergic to acetylsalicylic acid, reported discomfort in the area of teeth #44 and 45. After periapical radiographic and periodontal probing, it was decided to perform extractions, curettage of the apical granulation tissue and alveolar preservation (Fig. 1).

After 3 months, 2 Ticare implants (Mozo Grau; 4.2 × 8.0 mm and 4.2 × 11.5 mm) were placed (Fig. 2). After 15 days, the patient returned for a check and reported discomfort and swelling in the vestibular area of the implant placed in position #44; a radiolucency was observed radiographically at the apex of the implant. The lesion was diagnosed as in the acute suppurative stage. A surgical approach was performed to access the lesion, curette the granulation tissue and irrigate with sterile saline (Fig. 3). After the osseointegration period, the implant and tissue healing were monitored. At 1- and 3-year follow-up, the treated implant remained functional for prosthetic support, maintaining bone integration (Figs. 4 & 5).

Case 2

The 53-year-old female patient had no relevant medical history. Rehabilitation of the edentulous area of the right maxilla was evaluated. Two Ticare implants of 4.2 × 11.5 mm were placed in positions #15 and 16 (Fig. 6).

After 16 days of surgery, the patient reported pain. A radiolucency was observed at the apex of implant #15 and tooth #14 on a periapical radiograph (Fig. 7). Endodontic treatment of tooth #14 was performed owing to a negative vitality test. It was diagnosed as an acute suppurative stage lesion. The surgical approach entailed raising a flap to full thickness, with 2 objectives: accessing the apex of the implant to remove granulation tissue and pus, and performing periapical surgery on the adjacent tooth. The retrograde cavity was performed to access the lesion, curette the granulation tissue and irrigate with sterile saline (Fig. 3). After the osseointegration period, the implant and tissue healing were monitored. At 1- and 3-year follow-up, the treated implant remained functional for prosthetic support, maintaining bone integration (Figs. 4 & 5).
marginal bone defect was extensive and a collagen sponge was placed to avoid the collapse of the soft tissue during the healing period. After suturing, a postoperative periapical radiograph was performed (Fig. 7).

After 3 months, the healing abutments were placed in the second surgical phase to rehabilitate them prosthetically (Fig. 8). After 6 years, the implant and the treated tooth presented stable clinical parameters (Fig. 9).

**Case 3**

The 43-year-old female patient smoked 2 cigarettes per day. She had a coronal fracture of tooth #24 that had previously been endodontically treated. Tooth #25 was assessed and referred for root canal therapy prior to surgery. After careful extraction of the root, an implant (Ticare, 4.2 x 11.5 mm) was immediately placed in position #24 (Fig. 10).

Twenty days after implant placement, the patient came to the clinic owing to discomfort in the area. The radiograph showed a radiolucency apical and lateral to the implant. It was diagnosed as an acute suppurative periapical implant lesion. After raising the mucoperiosteal flap, it was found that the lesion had perforated the buccal bone. An ostectomy was performed and the granulation tissue was removed. Once the bony crypt had been cleaned, the stability of the implant was assessed, and owing to its mobility, it was placed more apically to stabilize it. After suturing, a postoperative control radiograph was performed (Fig. 11).

During the first year, healing of the soft and hard tissue was monitored (Fig. 12). At 4 years, the implant was still functional (Fig. 13).

**Discussion**

The literature describes the diagnosis of periapical implant lesions as occurring between 7 and 16 days after implant placement. Two of the treated cases were diagnosed within this period, and 1 after 20 days. The early diagnosis of periapical implant lesions during the osseointegration phase and early surgical treatment will lead to a higher survival rate of implants treated.
Surgical approach for periapical implant lesions

hence preventing the need for implant extraction.\textsuperscript{3}

The etiologies of the cases were diverse. In the first case presented, the tooth to be replaced had an endodontic apical lesion. After its extraction and despite the curettage of the alveolus and delayed placement of the implant, the surrounding tissue remained contaminated, favoring the development of a periapical implant lesion. Several authors have described similar conditions after implant placement in locations where the tooth being replaced had a periapical lesion.\textsuperscript{5, 12, 13}

In the second case, the implant was placed in mature bone. The source of contamination came from the adjacent tooth that previously did not present symptoms. The infectious process involved tooth and implant, and after the removal of the granulation tissue, its relation to the bony crypt was observed with the endoscope. Similar cases have been reported,\textsuperscript{7–9} although these were cases with the adjacent tooth endodontically treated; in this case, the adjacent tooth was vital before implant placement.

In the last case presented, the implant was placed immediately after the extraction of an endodontically treated tooth. Despite the curettage and abundant irrigation after the extraction, it is possible that there were epithelial remains that favored the development of a periapical implant lesion. Zhao et al. in a meta-analysis suggested that immediate placing of a dental implant into an infected site may increase the risk of implant failure.\textsuperscript{22}

Various therapeutic alternatives have been proposed to restore the osseointegration process in implants affected by periapical implant lesions. Curettage,\textsuperscript{6, 15, 23} irrigation with sterile saline\textsuperscript{1, 6, 24} or chlorhexidine,\textsuperscript{7} topical decontamination of the implant surface with calcium hydroxide paste\textsuperscript{25} or tetracycline paste,\textsuperscript{7, 15, 24} and guided bone regeneration\textsuperscript{4, 26} have been described, but there is no evidence of the efficacy of any of them. Further studies with larger patient samples are needed to expand knowledge about this lesion.

Conclusion

Up to 6 years of clinical and radiographic controls, all 3 cases showed complete healing of soft and hard tissue. Diagnosis and early treatment are crucial to ensure a correct osseointegration process and avoid implant failure.

Competing interests

The authors have no conflicts of interest related to this study.
Surgical approach for periapical implant lesions

Fig. 12A–C
(A) Frontal view at the 1-year follow-up.
(B) Lateral view at the 1-year follow-up.
(C) Periapical radiograph at the 1-year follow-up.

References


Influence of nonpassive fit in immediate loading: A pilot study

Abstract

Objective

The objective of this study was to evaluate the influence of nonpassively fitting prostheses on implant osseointegration and possible implant displacement during the healing period.

Materials and methods

Three healthy edentulous patients, ranging from 40 to 60 years, both sexes, were treated in the lower jaw with a 5-implant protocol. A fixed screw-retained prosthesis adapted from a prefabricated complete denture was installed. Implant position was recorded by analogic and virtual impressions, both at the time of implant placement and after the healing period. Also, abutment position was recorded before prosthesis installation. Level of misfit and stress were measured by 4 different clinical methods. Casts, prostheses and intraoral position of implants were compared throughout the study. Implant stability was assessed with resonance frequency analysis and torque control.

Results

Implant osseointegration occurred successfully in all 15 implants. Nonpassive prostheses were installed and passive prostheses were removed after 8 weeks, as implant position changed and strain was released. Implant final position was guided by abutment position in the restoration, as the prostheses showed no change in their structure.

Conclusion

Within the limitations of this study, passivity was not necessary to achieve implant osseointegration. Final implant position was modified, as tension was induced in a phenomenon similar to orthodontic movement. Prosthetic procedures to manufacture final restorations should rely on abutment position in the interim prosthesis rather than on initial implant position.

Keywords

Immediate loading; implant; passive fit.
Introduction

Immediate loading of microtextured implants with 1-piece fixed interim prostheses, in both the edentulous mandible and maxilla, has proved to be as predictable as early and conventional loading. For the mandible, the procedure is clinically well documented for the use of 4–6 implants loaded within 7 days after surgery. In summary of all prosthetic techniques described in the literature, procedures can vary between those in which a provisional restoration is prefabricated by CAD/CAM (together with a guided surgery protocol), those in which an impression is taken immediately after surgery in order to deliver a manufactured interim prosthesis, and those in which pre-existing complete dentures are adapted to implants by a chairside technique. Whichever method is used, difficulties in delivering a prosthesis with perfect fit are very common.

To begin with, computer-aided surgery is accepted to vary in accuracy, according to postoperative measurements. Although apex deviation of the implant (and not its coronal position) is always the most inaccurate aspect of the clinical outcome, many clinicians recommend the use of tooth-supported or mini-implant-supported templates rather than mucosa-supported guides, in order to improve accuracy. Furthermore, open- and closed-tray impression techniques, or even oral welding procedures, followed by dental laboratory prosthetic manufacturing usually need more than a short period to completely assess the fit of the restoration. Cases have been reported in which changes had to be made to adapt prostheses after manufacturing, even with the use of intraoral welding, while others appeared to have good fit. Finally, chairside procedures turning a complete denture into a hybrid screw-retained prosthesis are well known, and this approach has been described as a simple, low-cost and effective clinical method. Despite the advantage of improving the fitting by adapting the prosthesis with an intraoral procedure, this pickup technique involves using a great amount of acrylic resin to bond the abutments. Regardless of the pickup method or the resin used, polymerization always tends to induce some degree of tension between the abutments. This tension is released after the pickup itself and results in a misfit when installing the adapted prosthesis.

In light of these considerations a clinical misfit can be found very often when installing interim prostheses in a full-arch immediate loading procedure, regardless of the prosthetic approach selected. This implies a nonpassive structure tightened to implants with a certain amount of tension between them. In general, it is accepted that the need for passivity of fit is greater in implant-supported restorations than in conventional tooth-supported restorations because of the absence of a periodontal ligament. However, it is difficult to achieve this passive fit in immediate loading protocols and sometimes excessive torque is used to properly seat full-arch restorations. Nevertheless, implant survival rates in the literature and over many years have succeeded in validating these treatments. Moreover, there is a phenomenon that occurs during implant osseointegration that helps nonpassive fit become passive. This can be seen when taking out the interim prosthesis and assessing implant osseointegration 6–8 weeks after surgery. It appears that something changes during the healing period, as the prosthesis has a perfect fit and can be tightened without the need for increasing normal torque at this time. Tension is thus dissipated and osseointegration is successfully achieved, at least in the major percentage of cases. It seems that an element, if not all of the constituent parts, changes or moves to relieve this tension.

Gallucci et al. observed screw loosening in all edentulous patients treated with their pickup technique after 2 weeks of control. This problem was not present in subsequent prosthesis removals and was associated either with gradual wear of the titanium abutments in the zone of contact or with minor implant movement, as implants could respond to tension applied during screw tightening with minimal displacement. Furthermore, a randomized controlled trial by Karl and Taylor succeeded in proving that bone adaptation around statically and dynamically loaded osseointegrated implants occurred, causing a decrease in misfit strain provoked by a nonpassively fitting prosthesis. Moreover, micromotion induced during the implant healing period does not seem to be detrimental to osseointegration and only excessive micromotion is directly implicated in the formation of fibrous encapsulation in experimental models.

It is feasible that a modification in the whole bone–implant–abutment–prosthetic structure allows osseointegration in the presence of a nonpassive fit and also allows dissipation of the strain provoked. Thus, the main objectives of the current pilot study were to prove that passivity...
Nonpassive fit in immediate loading is not necessary itself to achieve osseointegration and to prove that slight implant movement helps to reduce tension and adapt its position to the prosthetic structure. For that purpose, information on the position of the implants was collected from an in vivo model before implant loading and after the healing period. Analog and digital casts helped assess accurate implant position, and clinical methods were used to assess the fit and passivity of the structures.

The null hypothesis was that passivity was not related to osseointegration success. Additionally, a second hypothesis was that recently placed implants can change their position, guided by the tension applied by a nonpassive screw-retained prosthesis. Otherwise, tension will remain after the healing period or will be released by the acrylic resin or any other element involved.

Materials and methods

For this preliminary study, 3 healthy edentulous patients, ranging from 40 to 60 years, both sexes, were treated in the lower jaw with a 5-implant protocol together with immediate restoration loading. To leave aside the influence of different types of bone, only inferior arches were included in the study, all of them with insufficient bone in which to place regular implants in the posterior area. Thus, 5 implants were placed between the mental foramina to support a fixed screw-retained prosthesis adapted from a prefabricated complete denture. Implant and abutment position were recorded and compared throughout the study, together with the level of misfit of the structures. Implant stability was assessed with resonance frequency analysis and torque control.

Under local anesthesia, a full flap was raised in the lower jaw to expose mental foramina using a specific surgical approach. The interforaminal area was flattened if necessary to level the bone height and develop an adequate bone width for installing regular-diameter implants. Osteotomies were performed so that distal implants could be slightly tilted to increase the anterior–posterior spread and so that implants could emerge at the occlusal or lingual aspect of the future prosthesis. A surgical guide was made by duplicating the prosthesis. Five dental implants (Straumann Bone Level, Straumann AG) of a minimum length of 10 mm were placed under mechanical torque control (Surgic Pro, NSK-Nakanishi) until 35 N cm² was reached. Manual insertion continued with a ratchet and torque control device without the driver (Loxim, Straumann AG) reaching breaking torque.

Before installing abutments, implant primary stability was measured with radiofrequency (ISQ, Osstell) by a second surgeon, blind to the surgical procedure, and recorded by an assistant. All implants reached a minimum of

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Implant stability values at Time 0 (T0) and Time 1 (T1).</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Implant position</strong></td>
<td><strong>ISQ values (buccolingual)</strong></td>
</tr>
<tr>
<td></td>
<td><strong>T0</strong></td>
</tr>
<tr>
<td>Patient 1 (jaw)</td>
<td></td>
</tr>
<tr>
<td>Left premolar</td>
<td>61</td>
</tr>
<tr>
<td>Left canine</td>
<td>67</td>
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<tr>
<td>Midline</td>
<td>72</td>
</tr>
<tr>
<td>Right canine</td>
<td>75</td>
</tr>
<tr>
<td>Right premolar</td>
<td>74</td>
</tr>
<tr>
<td>Patient 2 (jaw)</td>
<td></td>
</tr>
<tr>
<td>Left premolar</td>
<td>80</td>
</tr>
<tr>
<td>Left canine</td>
<td>84</td>
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<tr>
<td>Midline</td>
<td>76</td>
</tr>
<tr>
<td>Right canine</td>
<td>68</td>
</tr>
<tr>
<td>Right premolar</td>
<td>77</td>
</tr>
<tr>
<td>Patient 3 (jaw)</td>
<td></td>
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<td>Left premolar</td>
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</tr>
<tr>
<td>Left canine</td>
<td>70</td>
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<td>Midline</td>
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<td>Right canine</td>
<td>65</td>
</tr>
<tr>
<td>Right premolar</td>
<td>63</td>
</tr>
</tbody>
</table>
60 ISQ and this determined the possibility of immediate loading. Then, the first surgeon selected transmucosal pillar abutments (Multi-base, Straumann AG) according to soft-tissue height and torqued them to 35 N cm². Healing caps were used to facilitate suturing and repositioning of the soft tissue around implants. Interrupted sutures were performed using a polyglycolic acid resorbable suture (Atramat).

Before the pickup procedure, scan bodies were used to take a digital impression using an intraoral scanner (TRIOS, 3Shape). Later, impression posts were screwed in and splinted using light-activated polymerization resin (Triad Gel, Dentsply Sirona), separated with a small-diameter diamond bur (Fig. 2) and splinted again using a minimal amount of resin. A stone cast was made with a 2-step technique (passive cast technique) using a low-expansion dental stone (Elite Rock, Zhermack) and a vacuum machine. With these 2 procedures, the virtual and the analog position of the implants were recorded before any prosthetic procedure could modify it. This cast was called Cast 1 (C1) and represented the initial position of the implants (Fig. 3). Later, Multibase temporary abutments were installed and torqued to 15 N cm², checking for interferences with the hollow prosthesis and the occlusion. Using a pickup technique, they were bonded to the hollow prosthesis with autopolymerizing resin. This procedure was done without taking into account the contraction provoked by using a large amount of acrylic resin and thus the amount of stress generated by said polymerization. The wound was protected with a rubber dam and the prosthesis was held under patient occlusion during the setting of the material. Once the prosthesis had been removed, correct bonding of the abutments was assessed. If any abutment was not firmly attached, the pickup process was repeated. Acrylic resin was added where needed and the prosthesis was adapted to the new design, turning concavities into convexities to allow patient hygiene. Before delivering the prosthesis, a second stone cast was made using the same technique and materials. This cast was called Cast 2 (C2) and represented the position of the abutments in the prosthesis or the prosthesis itself (Fig. 4). For didactical reasons, the intraoral position of the implants was called Cast 3 (C3), meaning the in vivo position of the implants in the patients. Given the experimental model, a first comparison was made on the day of surgery and immediate loading (Time 0). Thus, the second surgeon measured the seating, fit and tension between the casts (C1, C2 and C3) and the assistant recorded the results (Table 2).

Four clinical methods were used to assess prosthesis fit, beginning with the most obvious method and continuing with the more detailed ones. That way, if a misfit was clearly recognized at any point, other methods were not necessary, but if there was not enough information to clearly recognize a misfit, the following method was used. The methods used, following previous revisions made by Kan et al., were, in order of accuracy: the alternate pressure technique (securing the prosthesis without screws and applying pressure alternately from 1 thumb to another to determine if rocking movement occurs); direct vision and tactile sensation (magnifying view and an explorer used to check misfit at the platform level); the 1 screw test proposed by Jemt (1 screw tightened at 1 terminal abutment and discrepancies observed at the other abutments); and the screw resistance test proposed also by Jemt (with a supposed acceptable misfit interface of 150 μ and a 300 μ distance between most prosthetic screw threads, a maximum of a half turn [180°] is allowed to completely seat the screw and achieve a torque of 10–15 N cm²). These 4 methods were used between casts as shown in Table 2. To begin with, the first test (Test A) entailed assessing the fit of the splint, passively made of impression posts, in the prosthesis cast (splint in C2), meaning the relationship between initial implant position and abutment position in the prosthesis (Fig. 5). To continue with, the second test (Test B) entailed assessing the fit of the prosthesis in the splint
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To end with, the third test (Test C) entailed assessing the fit of the prosthesis in the intraoral cast during installation of the interim prosthesis (prosthesis in C3; Figs. 6 & 7). Finding a nonpassive fit is the pillar around which the results obtained after the healing period are discussed.

Immediate radiographic control consisted of a digital panoramic radiograph to establish the correct fit of the abutments and initial bone crest around implants. A soft diet and careful hygiene were prescribed. Chlorhexidine rinses were prescribed until suture removal. Clinical controls took place at 1, 2, 4, 6 and 8 weeks. Hygiene, occlusion and prosthetic integrity were assessed at every appointment. Sutures were removed at 2 weeks without removing the prosthesis. Sutures remaining unreachable were left to resorb. A final panoramic radiograph was taken to assess the bone crest around the implants and osseointegration at 8 weeks. At this point, the prosthesis was removed and osseointegration was measured by the first surgeon as the assistant recorded the ISQ values. New tests at this time (Time 1) were performed to compare changes (Table 3). To begin with, the first test (Test D) entailed assessing the fit of the splint in the intraoral cast (splint in C3), meaning the possible position change of the implants through the healing period. To continue with, the second test (Test E) entailed assessing the fit of the prosthesis in the intraoral cast (prosthesis in C3), meaning the possible passive fit acquired through the healing period. To end with, the third test (Test F) entailed assessing the fit of the prosthesis in its initial cast (prosthesis in C2), meaning the possible change of the whole prosthetic structure (acrylic resin deformation and/or abutment movement inside) during the healing period. Finding a new passive fit implied that some element had modified its position or had suffered some deformation to dissipate the stress previously created by a nonpassive prosthesis installed at Time 0.

Moreover, scan bodies were used again to take a digital impression of the implant position at Time 1. Digital information was processed in a software program to determine possible variations of implant position and produce a virtual representation of any variation.

<table>
<thead>
<tr>
<th>Test A (splint in prosthesis cast C2)</th>
<th>Test B (prosthesis in splint cast C1)</th>
<th>Test C (prosthesis in intraoral cast C3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1 x</td>
<td>M2 -</td>
<td>M3 -</td>
</tr>
<tr>
<td>Patient 1</td>
<td></td>
<td></td>
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<tr>
<td>Patient 2</td>
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<tr>
<td>Patient 3</td>
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</table>


<table>
<thead>
<tr>
<th>Test D (splint in intraoral cast C3)</th>
<th>Test E (prosthesis in intraoral cast C3)</th>
<th>Test F (prosthesis in prosthesis cast C2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1 x</td>
<td>M2 -</td>
<td>M3 -</td>
</tr>
<tr>
<td>Patient 1</td>
<td></td>
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<tr>
<td>Patient 2</td>
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<tr>
<td>Patient 3</td>
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</table>


<table>
<thead>
<tr>
<th>Test G (splint in intraoral cast C3)</th>
<th>Test H (prosthesis in intraoral cast C3)</th>
<th>Test I (prosthesis in prosthesis cast C2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1 OK</td>
<td>M2 x</td>
<td>M3 x</td>
</tr>
<tr>
<td>Patient 1</td>
<td></td>
<td></td>
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<tr>
<td>Patient 2</td>
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<td>Patient 3</td>
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</table>


### Table 2
Passive fit assessment at Time 0.

### Table 3
Passive fit assessment at Time 1.

### Table 4
Passive fit assessment within 7 days.
Results

The initial results corresponded to Time 0. Implant stability measured with Osstell indicated values of 60 ISQ or more both in the buccolingual and mesiodistal aspects. Fitting tests were recorded with an “x” if fit failed to be passive according to the test, with a “-” if the test was not done or if the result was not conclusive, and with an “OK” if fit proved to be passive according to the test. For Tests A and B, the alternate finger test was more than conclusive to show a misfit in all of the patients. This was also validated with the 1 screw test. Misfit meant that the process of manufacturing the prosthesis had altered the position of the abutments in relationship to the implant position. The initial implant position and prosthesis did not coincide properly in all of the cases, and so resin contraction was assumed to have influenced the abutment position. For Test C, the only conclusive method was the screw resistance test, as soft tissue interfered with other assessment methods. As assumed in Tests A and B, the prosthesis installed failed to have a passive fit. More than a half turn was needed to seat the abutment and reach the desired 15 N cm². However, panoramic radiographs confirmed the proper seating of the prosthesis.

Later results corresponded to Time 1, which was at 8 weeks in all of the patients. Implant stability was assessed by torque verification and ISQ values in the same way that they were done at Time 0. For Test D, the alternate finger test was conclusive in only 1 patient, while more methods had to be used for the rest. Nevertheless, all of the patients showed a misfit between the splint and the intraoral cast. This meant that the initial position of the implants had changed from Time 0 to Time 1. For Test E, all of the methods succeeded in proving a correct fit of the prosthesis in C2 (original prosthesis cast). This meant that the prosthetic structure had not changed at all from Time 0 to Time 1. Thus, the prosthesis was not assumed to participate in the stress releasing process. Moreover, software was used to superimpose the implant position recorded at Time 0 and at Time 1. This process helped to confirm variation of implant position and helped to visualize the degree of variation between implant positions (Fig. 8).

In one patient, the prosthesis had to be removed within the first week to repair a fissure seen at the lingual aspect of the prosthesis, in order to prevent future fracture. To make the most of the situation, the patient agreed to extra tests at this particular time. For the purpose of this study, and out of established protocol, the same tests as planned for Time 1 were performed at that moment (Table 4). First (Test G), the splint failed to prove passivity in the intraoral cast with the second and third methods. This meant that the implant position had already changed within the first 7 days. Second (Test H), the prosthesis almost succeeded in proving total passivity in the intraoral cast, as it showed good results with the first 3 methods, but remained with a slight tension evident during the fourth method (screw resistance test). This meant that the prosthesis had improved its fit considerably within the first 7 days, but still showed a residual strain. Third (Test I), all of the methods succeeded in proving a correct fit of the prosthesis in C2 (original prosthesis cast). This meant that the prosthetic structure, specifically the abutment position, had not changed within the first 7 days.

Discussion

The collected data showed that passivity was not a decisive element to determine successful osseointegration of implants supporting a fixed immediately loaded prosthesis. The chairside method used to transform a complete denture into a hybrid prosthesis (pickup technique)
Nonpassive fit in immediate loading

resulted in a nonpassive structure that, for the purpose of this study, was installed provoking an amount of stress between the implants and abutments. Osseointegration was achieved in all 15 implants without showing bone loss or reduced stability after 8 weeks. Tension at the seating of the prosthesis disappeared without modification of the prosthetic structure. Implants showed variation in their position within 8 weeks, recorded with splints, casts and digital images. This was associated with stress release, as suggested by Gallucci et al., and could also be seen in one patient at an early stage. Implant movement was thought to occur during the first stage of the healing period, agreeing with Gallucci et al.’s findings at the 2-week screw loosening. Although digital images were not used to measure (in degrees or millimeters) implant variations, they helped visualize said movement or modification in implant position. In addition, no parameters of induced strain were considered. The literature suggests that there is a critical threshold of micromotion above which fibrous encapsulation prevails over osseointegration. Having said that, extreme precaution has to be taken regarding the amount of tension or level of stress generated by these procedures. To reduce the influence of bone type, only interforaminal areas of the jaw were included. However, many variables can have different influences on bone adaptation under stress and loading protocols.

As this was a preliminary study, the main limitations were the number of patients treated with this particular protocol. Although the phenomenon reported on has been observed in many patients after immediate loading protocols, more controlled cases need to be assessed. Given the foundations of these results and tests, future studies should consist of digital impressions only, in order to reduce clinical time and eliminate modifying factors such as polymerization, stone setting and clinical discrepancies between researchers.

Conclusion

A prosthesis delivered for immediate loading protocols involving implant placement in the edentulous mandible can induce a certain level of stress if passive fit is not achieved, without resulting in a negative influence on osseointegration. Excessive stress should never compromise biomechanical aspects or jeopardize bone healing around implants. Prosthetic procedures to manufacture final restorations should rely on abutment position placed in the interim prosthesis rather than on initial implant position, as freshly placed implants will adapt to the established abutment position and will not maintain their initial position. This phenomenon can be clinically (not histologically) compared to the bone adaptation that takes place in orthodontic treatment, where a force induces stress to move a tooth to a desired position. In a similar way, the prosthesis induces stress in the implant–abutment interface, and this provokes the recently placed implants to adapt to said induced position at an early stage of the healing period. Additionally, the force induced must be within certain limits, still unknown, such as recommended with orthodontic treatment.

Competing interests

The authors declare they have no competing interests.

Acknowledgments

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New perspectives in periapical surgery: Hemostasis

Abstract

Objective

The aim of the current investigation was to review techniques and materials available to achieve bleeding control during periapical surgery. An adequate bleeding control is crucial, since it improves vision in the surgical site, minimizes surgical time, enhances the root-end resection and filling, and reduces surgical blood loss, postsurgical hemorrhage and postsurgical swelling.

Method

An update is made of the aspects to be considered during bleeding control in periapical surgery.

Results

The hemostatic agents that have been proposed in the literature have characteristics that make them very different from each other, such as the mechanism of action, commercial presentation, hemostatic efficacy and systemic effects.

Conclusion

The hemostatic agents that have obtained the best results are ferric sulfate, calcium sulfate, aluminum chloride and epinephrine. Nevertheless, there is no consensus in the literature on which is the ideal hemostatic agent.

Keywords

Endodontic surgery; hemostatic agents; hemostasis; periradicular surgery.
Introduction

The ability to achieve sustained tissue hemostasis in the surgical site is crucial to the performance of periapical surgery. Adequate bleeding control improves vision in the surgical site, minimizes surgical time, enhances the surgical procedures (root-end resection, preparation and filling), and reduces surgical blood loss, postsurgical hemorrhage and postsurgical swelling.1

There is no consensus in the literature about what is the ideal hemostatic agent. Kim and Rethnam2 established in 1997 that a good agent should achieve hemostasis within a short period, be easy to manipulate, be bio-compatible, not impair or retard healing, and be relatively inexpensive and reliable.2 The aim of the current investigation was to review techniques and materials available to achieve bleeding control during periapical surgery.

Hemorrhage control

The hemostatic agents that have been proposed in the literature have characteristics that make them very different from each other, such as the mechanism of action, commercial presentation, hemostatic efficacy and systemic effects.

Bone wax

Bone wax is a nonresorbable material composed of beeswax (88%) and isopropyl palmitate (12%). It is applied to the bony walls with pressure and its mechanism of action is mechanical, tamponading the narrow spaces. Its translucency and deep encrustation into the bone make its removal difficult.3

Ferric sulfate and calcium sulfate

The mechanism of action of ferric sulfate is chemical, producing the coagulation of proteins, so it acts in a similar way to cauterization.4 Lemon et al. and Jeansson et al. studied the effects of ferric sulfate in rabbit mandibles; they achieved good hemostasis for 5 min.5 Scarano et al. compared the hemostatic efficacy of 20% ferric sulfate, calcium sulfate and gauze tamponade, and concluded that calcium sulfate produced a good level of hemostasis.6

Epinephrine

The amine-type sympathomimetic vasoconstrictors have been used as topical agents for the control of hemorrhage in periapical surgery (Figs. 1–8). Epinephrine produces vasoconstriction by stimulation of a-adrenergic receptors. Besner suggested that its use in periapical surgery can produce a systemic cardiovascular response.7 Vickers et al. evaluated the hemostatic efficacy and cardiovascular effects of ferric sulfate and pellets impregnated with racemic epinephrine, and concluded that both agents produced surgical hemostasis and found no statistically significant differences in systemic cardiovascular parameters with either of the materials.8 In a similar study, Vy et al. concluded that collagen sponges saturated with epinephrine provided excellent bleeding control without changes in blood pressure or heart rate.9

Aluminum chloride

In 2001, von Arx et al. used a paste composed of aluminum chloride and kaolin as a hemostatic agent,10 which is usually used to produce gingival retraction.11, 12 They applied different hemostatic agents in the calvaria of 6 rabbits: bone wax, ferric sulfate (Stasis), aluminum chloride (Expasyl) and a combination of Expasyl and Stasis.10 They concluded that Expasyl alone or in combination with Stasis was the most effective agent.10 Jensen et al. used the same study design to compare 5 hemostatic methods: Expasyl and Stasis; Expasyl, Stasis and freshening the bone defect with a bur; Spongostan; Spongostan and epinephrine; and electrocauterization.13 The most effective methods in the reduction of bleeding were Expasyl and Stasis combined (P < 0.05) and electrocauterization. Menéndez-Nieto et al. compared the hemostatic efficacy of epinephrine and aluminum chloride in 99 patients and concluded that aluminum chloride produced better results (P < 0.05; Figs. 9–14).

Other agents and techniques

Resorbable gelatin-based sponges,13, 16 oxidized cellulose,15 electrocauterization,13, 16, 17 carbon dioxide laser,18 chitosan19 and plant-based hemostatic agents20, 21 have been used to control hemorrhage in periapical surgery; however, their scientific evidence is limited.

Regarding adverse effects, in the presence of bone wax, scarring of the bony crypt is poor,
fibers of connective tissue appear, and there is no bone or hematopoietic tissue. In addition to delaying healing, bone wax increases the predisposition to infection and produces chronic inflammation with foreign body reactions. A histologic study showed a marked inflammatory tissue response toward aluminum chloride and bone wax within the immediate site of application, but no adverse tissue reactions were seen in the vicinity of the bone defects. The authors recommended that, before wound closure, the bony crypt be curetted or freshened using rotary instruments to remove any foreign material. Jensen et al. found that aluminum chloride and electrocauterization triggered adverse tissue reactions (necrotic bone, inflammatory cells, lack of bone repair); however, this tissue damage was not observed when the superficial bone layer was removed with rotary instruments. Peñarrocha-Diago et al. observed that the patients for whom aluminum chloride was used as the hemostatic agent suffered greater postoperative swelling than the patients treated with a vasoconstrictor. When ferric sulfate was used, normal healing with a slight foreign body reaction after curetting the cavity thoroughly and irrigating with saline was found. When the material was not completely removed from the cavity, foreign body reactions that delayed healing occurred, and in 2 of 10 cases, the specimens showed abscess formation in the center of the osseous defect. No adverse tissue reaction was found when calcium sulfate, epinephrine, resorbable gelatin-based sponges or chitosan were used.

**Conclusion**

Hemorrhage control is a key aspect of periapical surgery: A hemostatic agent should be biocompatible, easy to manipulate and able to achieve hemostatic efficacy in a short period. The hemostatic agents that have obtained good results are ferric sulfate and aluminum chloride; however, the tissue damage produced when the superficial bone layer was not removed and its relation to the prognosis must be considered. Other agents that have demonstrated good hemostatic efficacy without foreign body reactions are calcium sulfate and epinephrine.

**Competing interests**

The authors declare that they have no competing interests.
Hemostasis in periapical surgery

Fig. 11
Hemostasis after application of the aluminum chloride. The superficial bone layer was removed with rotary instruments.

Fig. 12
Evaluation of the retrograde filling with an endoscope.

Fig. 13
Tension-free soft-tissue flap closure.

Fig. 14
Periapical radiograph 1 year after the periapical surgery.

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    Hemostatic efficacy and cardiovascular effects of agents used during endodontic surgery. 
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Whereas Planmeca Ultra Low Dose protects patients from unnecessarily high doses, the new Planmeca CALM imaging protocol helps avoid retakes by compensating for movement. According to studies,2 patient movement may occur in up to 40% of cases, meaning that image quality is not optimal in a significant portion of CBCT scans. Planmeca CALM corrects artefacts caused by movement, resulting in sharper final images. The algorithm can be applied before the image is captured, as well as after the scan has been completed.

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References

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