Analysis of implant/abutment marginal fitting

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ABSTRACT

The success rate of osseointegrated implants is reported to be above 90%. Despite of the knowledge of the mechanisms of osseointegration, some faults still occur at implants systems. Recent researches assign those faults mainly to patient's prosthetic rehabilitation. The misfit at abutment-implant interface and the missing of a passive adaptation between the prosthesis and the abutment can lead prosthesis components, abutment screw or implants to fracture. This misfit can also generate a inadequate load distribution to marginal bone, bacterial plaque accumulation and even though, a complete loss of osseo integration. The origin of the loss of displacement of the prosthesis is a complex process, involving factors as: implant material properties, implant design, conical degree, machining accuracy of the components, fatigue, fluid and bacterial microleakage, masticatory functions and others. Considering the importance of a higher longevity to the osseointegrated implants and the necessity to obtain the best adjustment that is possible at the abutment-implant interface, this research will perform a literature review about the perfect adjustment needed at abutment-implant interface, yours biomechanical, functional, biological and clinical implications and also will study the different methods to analyze this interface.

UNITERMS

Dental implant, biomechanics; abutment, closing torque, implant-abutment interface, misfit.

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RESUMO

O índice de sucesso dos implantes osseointegrados gira em torno de 90%. Apesar de se conhecer bem os mecanismos da osseointegração ainda ocorrem falhas nos sistemas de implantes. Pesquisas recentes atribuem essas falhas, principalmente, à reabilitação protética do paciente. O desajuste entre a base do implante e o pilar protético e a falta de adaptação passiva entre a prótese e os pilares podem levar a fraturas tanto dos componentes protéticos quanto do parafuso do pilar ou do próprio implante; pode também levar à distribuição inadequada das forças ao osso de suporte, acúmulo de bactérias e até mesmo à perda da osseointegração. A natureza da perda ou deslocamento das próteses é complexa, envolvendo fatores como: material do pilar protético, tipo de encaixe, grau de conicidade, precisão de usinagem dos componentes do sistema, fadiga, penetração de fluidos bucais, variedades de mastigação, dentre outros. Considerando a importância de uma longevidade maior dos implantes osseointegrados e da necessidade de se obter a melhor adaptação possível entre base do implante e pilar protético, esse trabalho realizou uma revisão da literatura sobre a importância do perfeito ajuste entre esses dois componentes, suas implicações biomecânicas, funcionais, biológicas e clínicas e ainda, levantar os diferentes métodos para estudo dessa interface de união.

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UNITERMOS

Implante dentário, biomecânica; pilar protético, torque de apertamento, interface implante-pilar protético, desajuste

INTRODUCTION

The success rate of osseointegrated implants is reported to be above 90%. Despite of the knowledge of the mechanisms of osseointegration, some faults still occur at implants systems. Recent researches assign those faults mainly to patient's prosthetic rehabilitation. The misfit at abutment-implant interface and the missing of a passive adaptation between the prosthesis and the abutment can lead prosthesis components, abutment screw or implants to fracture (Sakaguchi & Borgersen[25], 1995; Norton[20], 1999).

Functionally, this misfit can cause overload at the abutment and distribute not axial load along implant and marginal bone. The gap generated by this misfit can also be a trap for bacteria colonization, which might cause inflammatory reactions in the peri-implant soft tissues (Jansen et al.[16], 1997; Traversy & Birek[29], 1992; Abrahamsson et al.[2], 1998).

The origin of the loss of displacement of the prosthesis is a complex process, involving factors as: implant material properties, implant design, conical degree, machining accuracy of the components, fatigue, fluid and bacterial microleakage, masticatory functions and others. Presently, authors are worried about finding means to analyze the misfit between implant/abutment and to improve this interface using new implant designs and prosthetics components, torque control, machining accuracy (Binon[5], 1995) or others means. Animal experiments and clinical studies have shown that osseointegration of the implants is related to its biomechanics, assigning components loss or fracture to mechanical faults (Stegariou et al.[34], 1998).

Considering the importance of a higher longevity to the osseointegrated implants and the necessity to obtain the best adjustment that is possible at the abutment-implant interface, this research will perform a literature review about the ideal adjustment needed at abutment-implant interface, yours biomechanical, functional, biological and clinical implications and also will study the different methods to analyze this interface.

LITERATURE REVIEW

To facilitate the reading, the literature review was divided into topics: tightening torque; bacterial microleakage; abutment design and conical-degree; occlusion; methods to analyze implant/abutment marginal fitting.

TIGHTENING TORQUE

According to Burguete et al.[7], 1994, there are three classes of tightening methods: a) torque control; b) angle control and c) torque/angle control. The torque can also be applied by hand or by a torque control device. The maximum torque reached by hand is 20Ncm and the habitual is of 10Ncm according to Haack et al.[11], 1995.

In the process of loosening of the abutment screw, initially, external forces, transverse or axial, applied to the screwed joint during chewing lead to the effective erosion of the preload (at this stage the greater the joint preload, the greater will be the resistance to loosening). In the second stage of loosening, the preload is below a critical value so that external forces and vibrations cause the mating threads to turn or "back off" (Bickford[4], 1981).

Carr & Larsen[8], 1995, measured torque failure levels of tissues during the abutment tightening on implants of three different biomaterials (commercially pure titanium, hydroxyapatite coated and Ti-6Al-4V) placed into the edentulous posterior maxillae and mandibles of baboons. They concluded that implant/tissue interface of baboons is able to resist to tightening torque of almost 35Ncm and that hydroxyapatite coated implants are more resistant to the torque than the metallic one.

The abutment tightening torque varies according to the material and implants system. Implant Innovations standard abutment, for example, is tightened with 10Ncm, UCLA - 20Ncm and STA/STR - 32Ncm.

Lang et al.[18], 1999, examined the implant/abutment interface and the tightening force transmitted to the implant with and without a counter-torque device during the tightening of the abutment screw. The counter-torque device turns the force used on the abutment tightening parallel to the implant axis, without torsional forces, as shown at Figure 1.

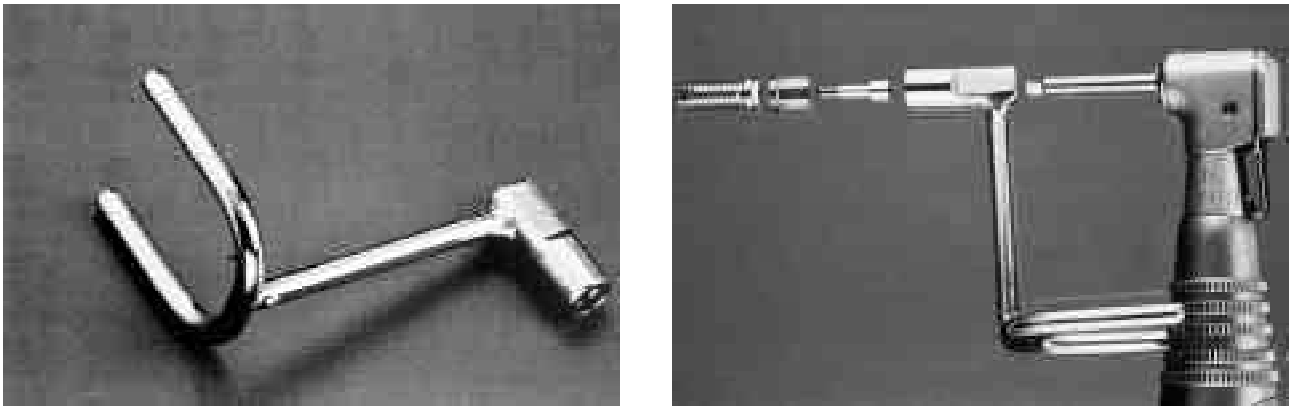

FIGURE 1 – Figure a e b: counter-torque device of Bränemark Implants System.

CeraOne and Procera abutments were tightened with 32Ncm, Estheticone with 20Ncm and AurAdapt with 45Ncm. It was concluded that when the counter-torque device was used, the magnitude of the torque force transmitted to the bone was less than 10% of the recommended preload tightening and when the counter-torque device was not used this force was significantly increased to 91%.

Bacterial microleakage

It is postulated that a potential microscopic space exists at the abutment/implant interface along the abutment screw threads and at the base of the screw chamber. This misfit may facilitate microleakage of fluids and macromolecules originating from crevicular fluid and/or saliva (Gross et al.[10], 1999).

In 1993, Quirynen & Steenberghe[23] investigated the presence of microorganisms in the inner part of an endosteal implant of the Branemark system (implant of two stages) on nine patients. All screws harboured a significant quantity of microorganisms, mainly coccoid cells (86%) and nonmotile rods (12,3%). On the other hand, none of those microorganisms were found on sleeping implants. The microbial leakage at the abutment/implant interface can lead to the loss of marginal bone and also interferes on the treatment of peri-implantitis.

Jansen et al.[16], 1997, studied, in vitro, 13 different combinations of nine implants systems about microbial microleakage in the abutment/implant interface and also about the gap degree on that interface. After 14 days, 69% of the implant system showed microbial leakage. The width of the marginal gap between the prefabricated components, measured with a scanning electron microscope, was less than 10µm in all systems. The medium value of the marginal gap was lower than 5µm and the abutment Octa (Bonefit) showed the most width misfit (12µm). The most important result of this study was that good marginal fit of implant components did not prevent microbial leakage.

An experiment was performed by Abrahamsson et al.[1,2], 1998, to examine if the material used in the abutment influenced the quality of the mucosal attachment and to study the location and composition of plaque associated lesions in the mucosa adjacent to implant systems (Astra, ITI and Branemark) that differed with respect to both geometry and dimension. Plaque accumulated on all implants surfaces with signs of inflammation containing numerous PMN cells and some macrophages. On two-stage implant systems, Astra and Branemark, a second discrete inflammatory cell infiltrate was present in the connective tissue lateral to the abutment/implant interface. Abutments made of gold presented mucosa attachment greater than abutments of titanium and ceramic.

Gross et al.[10], 1999, assessed the degree of microleakage in the abutment/implant interface at varying closing torques: 10Ncm, 20Ncm and the torque recommended from the manufacturer (Spline - 28Ncm; CeraOne - 32Ncm; Steri-Oss - 35Ncm; 3i - 20Ncm and ITI - 35Ncm). It was verified that microleakage decreased significantly as torque increased from 10Ncm to recommended values and concluded that recommended torque value may reduce potential adverse effects of microlekage. Leakage values of all samples diminished to the minimal range at the recommended closing torque of 35Ncm. Steri-Oss implants showed values of microleakage higher than others experimental groups.

Abutment design and conical-degree

The design of the interface between components within its complex may have a profound influence on the long-term function of the implant-supported prosthesis (Norton[19], 1997).

Sutter et al.[28], 1993 and Norton[20], 1999, evaluated the loosening torque as a percentage of tightening torque for conical abutments (OCTA from ITI – 8-degree and Astra Tech – 11-degree internal cone). Sutter et al.[28], 1993 verified that the loosening torque for OCTA abutment was 10 to 15% higher than the tightening torque used (50Ncm), while on standard screwed abutments the loosening torque is 10% lower than the tightening torque. This result is not in agreement with Norton[20], 1999, which concluded that loosening torque was approximately 80 to 85% of the tightening torque for all samples tested.

Binon[5], 1995, evaluated 13 implants having external hexagonal extensions, one having internal hexagon (Paragon) and another having internal octagon (Omniloc), for machining accuracy and rotational freedom. Considering components combinations from the same manufacturer, the least amount of rotational freedom was recorded for the abutment with internal hexagon (Paragon - 1,4º), followed by Implants Innovations and Crossmark (4 a 4,6º – external hexagon). Omniloc (7,5º), Implants Innovations and NP (6,7º) recorded the greater rotational freedom.

Baulfour & O'Brien[3], 1995, evaluated the external hexagon, internal octagon and internal hexagon implants and abutments. Overall, the internal hexagon design was found to provide the highest degree of stability and the abutment screw failed in a way that the failed abutment screw could be removed and the implant still be restored. In the external hexagon implants the failed occurred so that the implant could be unrestorable. On cyclic fatigue-loading tests, the internal octagon implants showed the highest resistance (400N), followed by internal hexagon implants (367N) and external hexagonal implants (242N). It was concluded that internal hexagonal implants system was the most effective design tested perhaps because of the 1-degree flare at the base of the mating hexagon on its prosthetic abutment.

Occlusion

Any transverse or axial external force that causes a small amount of slippage between the threads, no matter how small, releases some of the stretch and some of the preload is lost (Burguete et al.[7], 1994).

Rangert et al.[24], 1995, verified that the higher incidence of the fractures occurred in implant-supported prosthesis of the posterior region (90%) and that in-line implant placement and additional load factors, including prosthesis misfit, may cause overload to the system. It was also concluded that single-molar, single-implant situation might have a high susceptibility to bending overload. Therefore, the occlusion should be developed so that only centric contacts exist, what is corroborated by Ichikawa et al.[14], 1994. On their research, the group that presented bone decreased gradually after superstructure placement (medium of 0,4mm/year) also presented occlusal overload (490N), while that the majority of the implants (28) presented constant bone level or formation around the implant (medium of 0,1mm/year). The results suggested that bone resorption/formation around the implant was related to occlusal stress, and that adequate occlusal stress should be exerted gradually on the implant at each phase after the implant placement.

Isidor[15], 1996, compared the breakdown of bone around five screw-type implants from Astra System (3.5x8mm), in monkeys, when following excessive occlusal load (supra-occlusal contact: group 1) or plaque accumulation (group 2). The implants were followed by clinical and radiographic exams during 18 months. This study showed that occlusal overload can be the main factor for an already osseointegrated implant to fail, while plaque accumulation can cause progressive marginal bone loss. It was also verified that a lateral load is more detrimental to oral implants than an axial load.

Methods to analyze implant/abutment marginal fitting

Presently exists preoccupation to analyze the misfit degree between implant/abutment. Many authors are worried about the clinical significance of that misfit and are studying methods to analyze this.

RADIOGRAPHIC ANALYSIS

Repeated radiographic examinations aim at determining the bone level around the implants and revealing possible formation of a soft tissue membrane between the implant and surrounding bone, what indicate that the implant is loosening its bony anchorage (Hollender & Rockeler[13], 1980). Radiographic examinations may also check abutment fitting to implant and verify the marginal fitting of the prothesis.

In 1986, Cox & Pharoah[9], observed a problem in adapting the long-cone paralleling radiographic technique to the edentulous jaw with advanced bone resorption because of the limited space. Because of that a new radiograph holder has been designed to record the image of the apical portion of the implant and an accurate image of the alveolar crest. The holder evaluated provided an accurate, highly reproducible method of obtaining serial radiographs of osseointegrated implants what allowed to measure marginal bone loss lower than 0.10mm around the implants (bone loss medium index for an year). Hollender & Rockler[13], 1980, analyzed the long-cone paralleling radiographic technique efficacy on 13 Bränemark implants of different heights placed on jaws of elephant. The ideal stereoscopic model was obtained when the projection was changed 6º to 12º in the horizontal plane between the two exposures and the projection kept perpendicular to the film in the vertical plane. Stereoscopic radiographs were doubtless found to be superior in relation to single radiographs both for estimating the bone level around the implant and for the detection of infrabony pockets and gaps between fixture and bone, however, the observer has to have a good stereoscopic visional ability.

In 1999, Ormaechea et al.[21], determined the maximum permissible x-ray tube angulations that could be used to verify the fit of an abutment to the implant using Branemark implant system. The abutments screws were tightened using a manual screwdriver and gaps of 21, 42, 50, 100 and 150µm were left between the abutment and the implant. The x-ray tube angulations varied from 0, 5, 10 to 15º, vertically. It was verified that the maximum x-ray tube vertical angulations should be between 5 and 10º because as the angulations of the x-ray tube increased, the ability to identify implant/abutment gaps decreased. The results also showed that gaps of at least 21µm already could be observed using long-cone paralleling radiographs.

BACTERIAL MICROLEAKAGE

It has already been stated that overloading of an oral implant can result in loss of marginal bone or complete loss of osseointegration at implants where osseointegration has been achieved. However, a long-term inflammation around peri-implant tissues may increase marginal bone loss. Authors as: Quirynen & Steenberghe[23], 1993; Jansen et al.[16], 1997 and Gross et al.[10], 1999, studied the presence or not of a marginal gap between implant and abutment using bacteria microleakage and/or fluid penetration. Those researches have already been discussed before (Bacterial Microleakage).

MACHINING ACCURACY

Schult[26], 1994, measured and compared the external hexagon dimensions at three different points on eigh implants of six systems (Dentsply, Impla-Med, Implant Innovations, Interpore International, Nobelpharma e Steri-Oss), using a measuring caliper of 0.0001inch accuracy. The results indicated a considerable difference in the quality control at implant manufacturing companies, mainly on Nobelpharma implants (medium of 0,0014 inch). The lower variation occurred on Implant Innovations system (médium of: 0,0003 inch).

Binon[5], 1995, evaluated 13 implants having external hexagonal extensions, one having internal hexagon (Paragon) and one having internal octogon (Omniloc), for machining accuracy and rotational freedom using a digital micrometer and a micrometer microscope of 1mm of accuracy. Abutment to implant hexagonal extension rotational freedom (movement) was measured in degrees using a large calibrated protractor table that firmly secured the implant in the center of a180 degree circle. The results showed that Implants Innovations System and Crossmark were the most tolerant according to manufacturer data. Paragon implants system, Crossmark and Implant Innovations have shown the lowest degree of rotational freedom (1,4º; 4-4,6º, respectively). In the mixed component group, the least amount of rotational movement was recorded for the combinations NP/IMP, ISS/IMP, 3i/IMP e NP/3i.

Scanning electron microscopic analysis

The scanning electron microscopic analysis was used by Binon[5], 1995 and Jansen et al.[16], 1997 to measure the gap between the abutment and implant. Binon[5], analyzed the accuracy of the implant/abutment interface on ScrewVent implants with raises of 20, 100 and 200x and encountered a marginal gap of 45µm.

Jansen et al.[16] analysed the marginal fit of one implant/abutment assembly of each type with scanning electron microscopy in 12 locations with magnification of 50 and 775x in a viewing angle parallel to the outer parts of the interface zone. Implants with a flat interface (Calcitek, Ha-Ti, IMZ, IMC e Frialit-2) were thus viewed at a right angle to their long axis. Interface plane (ITI-OCTA e Semados) were only slightly angulated to be analyzed. Implants with a conical interface (Ankylos, Astra e conical Bonefit) were viewed from above, with the implant slightly tilted according to the interface angle. The marginal gaps of all prefabricated parts were smaller than 10µm. Only OCTA abutment showed a maximum gap of 12µm. The median gap value found was under 5µm for all systems.

Discussion

The misfit between abutment and implant interface has many clinical implications as: abutment overload; screw loosening or fracture or even of the implant itself; incorrect transmission of forces to implant and marginal bone and microbial proliferation. Those factors can lead to a persistent inflammation around peri-implant tissues (Traversy & Birek[29], 1992; Smedberg[27], 1996; Jansen et al.[16], 1997; Abrahamsson et al.[1], 1998).

There are a lot of variables that may influence the adjustment between abutment/implant, including the variety of implant system and abutments on market. About the tightening torque, Lang et al.[18], 1999, verified that a counter-torque device used during the abutment tightening influences significantly the force transmitted to marginal bone (less than 10% of the preload is transmitted to the bone). This method of tightening torque (with angle-control) is also considered effective by Burguete et al.[7], 1994. However, only Branemark implant System has this kind of device and it is necessary to analyze better relationship between this device, the preload transmition to the bone and the quality of implant/abutment interface. If those factors have a positive relationship, this device should be adopted by others implant manufacturers that still don't have this kind of device. Further than diminish the preload transmitted to marginal bone, it is also important to analyze the force supported by surrounding tissues (Carr & Larsen[8], 1995 believe that this force is of 35Ncm on monkeys) and, the kind of material used on the abutment.

The gap between implant and abutment is an ideal place for bacterial proliferation and fluid microleakage, what can lead to peri-implantitis (Quirynen & Steenberghe[23], 1993; Jansen et al.[16], 1997; Abrahamsson et al.[1], 1998; Gross et al.[10], 1999). Studies such as from Gross et al.[10], 1999, show the influence and the importance of using the tightening torque recommended from the manufacturer to diminish microleakage. According to Haack et al.[11], 1995, the maximum manual torque reached is of 20Ncm and the habitual is of 10Ncm, values that don't reach the torque recommended to diminish microleakage to minimum values (Gross et al.[10], 1999 - 35Ncm). It is important to say that the force applied in the tightening torque is only valid if the machining and adjustment degree between abutment and implant were proper because high levels of tightening torque would not produce the desired result on components that don't have proper mortise. It still important to determine the maximum misfit degree permitted on implant/abutment interface so that minimum screw loosening, bone resorption and peri-implant soft tissue inflammation happen.

The abutment conical degree and the kind of mortise also influence on the long-term function of implant-supported prosthesis. Sutter et al.[28], 1993, Binon[5], 1995, Baulfour & O'Brien[3], 1995, Norton[19, 20], 1997 and 1999 showed that tapered abutments may enhance mechanical properties of the system. However, according to Norton[20], 1999, cold welding might result in a lack of retrievability, although conical abutment have been presented to diminish micromovement and loosening.

Dental implants are submitted to different occlusal loads, what may lead to fracture of implants and abutments, loss of components or even marginal bone resorption. Rangert et al.[24], 1995, concluded that single-molar, single-implant situation may have a high susceptibility to bending overload. Therefore, the occlusion should be developed so that only centric contacts exist. It was also verified that the placement of implants is a crucial factor to consider in a three-unit posterior prosthesis. Ichikawa et al.[14], 1994 e Isidor[15], 1996 also agree that lateral forces are more harmful to implants.

Many methods have been used to analyze the fitness between abutment and implant. Even though radiographic examinations give only two dimensions information about three dimension objects, it is an effective method for longitudinal evaluation of bone loss and also to measure the marginal fit at implant/abutment interface (Plotnick et al.[22], 1978; Hollender & Rockler[13], 1980; Ormaechea et al.[21], 1999). The intra oral long-cone paralleling technique is recommended to obtain reproducible radiographies with consistent image geometry and to detect marginal gap on implant/abutment interface (Hollender & Rockler[13], 1980; Cox & Pharoah[9], 1986; Ormaechea et al.[21], 1999). Bacterial solutions (Quirynen & Steenberghe[23], 1993 and Jansen et al.[16], 1997) or fluid microleakage analysis (Gross et al.[10], 1999) were also used to detect the misfit degree of this interface. The torque applied on abutment tightening and the implant evaluated influence the microleakage (Jansen et al.[16], 1997; Gross et al.[10], 1999).

Schult[26], 1994 and Binon[5], 1995, evaluated the machining accuracy of different implant systems. Schult[26], 1994, has found the lowest variation on Implant Innovations system and the highest on Nobelpharma implants system, according to manufactures data. Binon[5], 1995, has also found smaller variations on Implant Innovations and Crossmark systems. This research also analyzed the rotational freedom between implant and abutment and found the lowest values in Paragon (1,4º), Crossmark, Implant Innovations and Impla-Med systems. In the mixed component group, the least amount of rotational movement was recorded for the combinations NP/IMP (3,5º,) ISS/IMP (4,2º), 3i/IMP (4,3º) and NP/3i(4,9º). The retrievability among implant systems should be analyzed because although manufacturers declare that their implants are compatible with others systems, many researches noticed variations on tolerance among the systems (Binon et al.[6], 1994; Binon[5], 1995; Hagiwara et al.[12], 1997; Kano[17], 1998).

The scanning electron microscopy analysis is another effective method to analyze the disadjustment between systems components. However, this method is not viable for clinical appliance**.** Binon[5], 1995, found, through scanning electron microscopy, the medium misfit between implant and abutment of 49µm for Branemark implant system. This result was not in accordance with the result found by Jansen et al.[16], 1997 (5,0µm). This difference, according to Jansen et al.[16], 1997, occurred because Binon[6] had measured the abutment including its rounded edge, which do not influence the interface between implant and abutment, which limits microbial leakage.

Final Considerations

According to the literature review, one can conclude that the tightening torque is an important factor to improve mechanical and biological properties of the interface between implant and abutment. Despite of that, the use of the torque recommended from the manufacturer may potentially reduce the adverse effects of microleakage although microbial and fluid penetration occur on implant/abutment interface even if a good marginal fit between components exist. This microbial colonization was not observed on submerged implants. Among the methods to analyze the adjustment between implant and abutment, the scanning electron microscopy showed a marginal gap on implant/abutment interface that varied between 5µm and 45µm, revealing itself as an efficient method for this king of analysis.

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