



Zirconia dental implants: An overview

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Zirconium dioxide (ZrO_2), or zirconia as it is more commonly known, was discovered in 1789 by the German chemist M. H. Klaproth. This material was introduced into dentistry only a few decades ago. Zirconia became an attractive alternative material in dentistry because of its high aesthetic potential and comparable strength to the conventionally used metals. In the field of implant dentistry, titanium has been the mainstay in implant manufacturing. However, zirconia became a viable option because it possesses superior properties, including a higher tensile strength, compressive strength and modulus of elasticity compared with either titanium alloy or commercially pure titanium (Table 1).

Manufacturing zirconia

The zirconia used in dentistry today is not merely the zirconium dioxide discovered in the eighteenth century. The commercial-grade zirconia has several modifications that enhance its properties. In its pure phase, zirconia has a low shear strength and is very brittle, essentially making it useless as a dental material. The addition of small amounts of aluminium oxide and yttrium oxide increases the modulus of elasticity and helps to stabilise the material. This combination of oxides is mixed in the powder state and placed in a sintering oven to produce a monoclinic crystalline structure, with equally spaced,

Features	Bone	Titanium alloy	Commercially pure titanium	Zirconia
Tensile strength (MPa)	104–121	993	662	1,000
Compressive strength (MPa)	170	970	328	2,000
Modulus of elasticity (GPa)	10.0–15.0	113.8	103.0	200.0

Table 1: Zirconia compared with titanium alloy and commercially pure titanium.

non-overlapping particles (Fig. 1). Although the monoclinic crystal is a strong material, cracks can propagate easily in the structure, making it less desirable for use in a long-term implanted prosthesis.

In order to eliminate this issue, today’s zirconia is also put through a process known as hot isostatic pressing (HIP). The high pressure under which the monoclinic zirconia is placed during HIP processing causes condensation of the particles and results in a tetragonal crystalline structure, where the particles appear to overlap (Fig. 2). The significance of this innovation is that it imparts the ability to stop crack propagation. When the surface of HIP-processed zirconia is prepared, any micro-cracks that may result are quickly stabilised as tetragonal particles expand into the monoclinic structure and fill the void. The self-repairing property is also known as the “airbag effect”. The additional stability gained by the HIP process has enabled zirconia to be used for multiple medical prosthetic devices, including auditory, finger, hip, and dental prostheses.

Indications and contra-indications

Indications for zirconia implants are as follows:

1. all aesthetic zone cases, especially in those with a scalloped, thin biotype gingival architecture and in critical gingival papillary build-up cases;

2. patients with metal allergies and chronic diseases resulting from them; and
3. as an alternative to titanium dental implants in any intraoral location.

Contra-indications are the following:

1. patients that exhibit a lack of compliance with post-operative instructions;
2. a lack of operator clinical and technical knowledge about implant surgery and prosthetic restorations; and
3. any other general contra-indications to implant rehabilitation with one- or two-piece titanium implants, such as bruxism.

Bone relationship

One-piece implant concept

The one-piece implant allows axial forces to be applied to a solid but flexible structure without attachments, made entirely of one material with no physical interruption and excellent flexural strength. One of the major advantages of the HIP-processed zirconia is its ability to be prepared intraorally, as ceramics do not conduct heat like metal or natural tooth substance. Preparation of the abutment can occur immediately after insertion or after osseointegration and allows what is essentially a custom abutment to be prepared. Unlike one-piece ti-

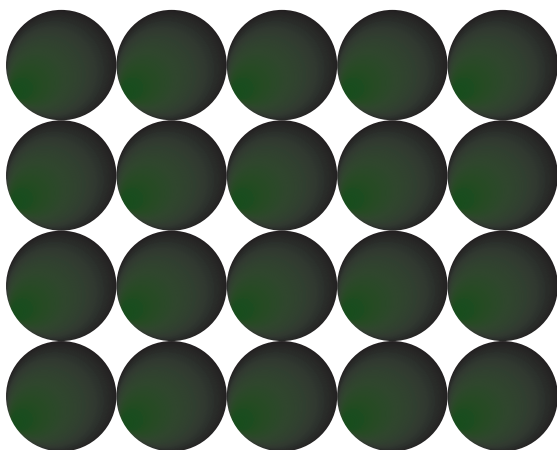


Fig. 1

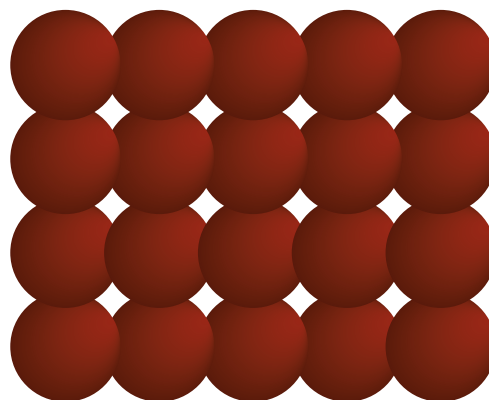


Fig. 2

Fig. 1: Monoclinic crystalline structure. **Fig. 2:** Tetragonal crystalline structure.



Fig. 3

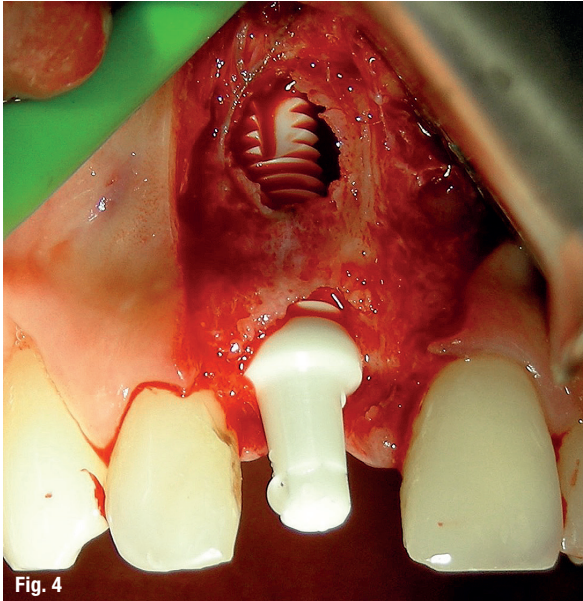


Fig. 4

Fig. 3: Post-op situation showing an optimal result. **Fig. 4:** Situation during a high-risk procedure, implant threads visible.

tanium implants, which were often used for immediate loading procedures and had not provided predictable success, the goal of one-piece zirconia implants is to provide immediate aesthetics. One should also consider the differences in the cost of manufacturing and the environmental implications for one- and two-piece implant systems. The need for more efficient and environmentally friendly industrial operations is critical and the push towards a more economical solution will continue.

Importance of proper planning

Proper implant positioning at the time of insertion is critical to the success of the restoration and aesthetics of the final product. The abutment in a one-piece system can allow for only around 20° to 25° of correction through preparation of the coronal aspect. In order to properly determine the ideal implant location, wax-ups and digital prototypes should be utilised when possible. When proper implant placement is achieved, the abutment will be in such a position that forces transmitted along the long axis will be favourable and the unfavourable loading will be minimised. Forces of the final crown are supposed

to be placed on the shoulder of the implant (if possible). Such a relationship can then translate into a good long-term marginal bone level stability and a healthy, durable restoration (Fig. 3).

Tulip-shaped abutment neck

The tulip-shaped neck of the abutment is analogous to the cervical shoulder area of the implant. This area marks the transition between the implant and the abutment. It allows the implant to be inserted at a variable depth to establish the proper emergence profile with optimal gingival contour and enables correction of axial divergence by up to 20 per cent. The design and material of the implant allow vertical placement in bone to vary by up to 1.5 mm. Since zirconia is white, there is little aesthetic risk from not sinking the implant deep enough. If the crestal bone architecture is flat, the implant shoulder does not have to be countersunk.

For aesthetic reasons, such as thickness of mucosa and need for vertical adjustment of the preparation border, or with uneven crestal bone architecture, it is frequently necessary to countersink the implant up to the transition of the implant tulip to a maximum of 1.5 mm. When attempting to place immediate implants in the aesthetic zone, the shoulder or tulip insertion should extend to cover the edge of the extraction socket to achieve greater stability and the same results as with tapered implants. After five years of clinical use and studies, the current recommendation is to try to avoid over-insertion of the shoulder when not needed in non-aesthetic areas, as it may lead to a greater degree of bone loss over time.

Angled abutments

When placing implants in the anterior region, the operator often has a tendency to base the implant angulation off of the future restoration, which can consequently lead to buccal cortex violation. With the implant body at the correct angulation, the restorative components may not be properly angled for a good aesthetic result; often, the abutment protrudes buccally, leaving little room for fabrication of a natural-appearing crown. Two-piece implant systems may use angled abutments to compensate for this discrepancy. In one-piece zirconia implants, the issue is easily addressed by preparation of the abutment aspect to the desired angle, up to a maximum of 20° to 25°. This is possible because the wide implant shoulder, in combination with the large abutment, allows an even force distribution, which minimises bone loss and increases longevity of the restoration.

Soft-tissue relationship

Zirconia surface

The zirconia implant surface is biocompatible with the oral soft tissue. As a ceramic, zirconia inhibits formation of plaque and promotes a healthy soft-tissue attachment.

There has been no evidence of any inflammatory reaction or irritation to the gingiva from the zirconia surface.

Implant shoulder

The implant shoulder may be adjusted to better follow the scalloping of the gingiva to obtain the most aesthetically pleasing results in the anterior region.

Micro-gaps

Eliminating the micro-gap between the implant body and abutment eliminates the possibility of bacterial attachment and inflammation. Without a micro-gap, there is less long-term soft-tissue irritation.

Gingival papillary growth

The gingival soft tissue has been found to have an affinity for the zirconia surface, which leads to excellent aesthetics. Not only can zirconia preserve the existing gingival papillary height, but it has even been observed to induce gingival growth. For papillary build-up cases, zirconia has a distinct advantage over conventional titanium implants. The best results have been shown in cases with a thick and flat gingival biotype, as well as a good emergence profile without violation of the biological width.

Surgical considerations

For the best aesthetic results, one should start soft-tissue contouring at the time of tooth extraction in the case of immediate placement and when the provisional is first made in the case of the conventional protocol. When planning an immediate placement case, a conservative, atraumatic extraction will aid tremendously in maintaining the best gingival architecture. The provisional should have a smooth and well-contoured finishing line to facilitate the best gingival health. Often, the tissue will be inflamed at the time of surgery, especially with immediate implant placement, because of a pre-existing infection in the tooth. Therefore, it is quite common to have what appears to be recession of the tissue during the healing process. As the zirconia surface is biocompatible and does not trap plaque, tissue inflammation will subside in one to two weeks after placement. Flapless surgery is a good alternative to help with soft-tissue maintenance.

Intraoral adjustments

Implant selection

Several factors must be taken into consideration when planning for one-piece zirconia implants. The minimum height required for one-piece zirconia is thought to be 7 mm (Fig. 4). Bone grafting procedures should be undertaken when necessary to achieve this minimum height. If the crestal bone architecture is flat, the implant does not need to be countersunk; however, if the soft-tissue aesthetics dictate that the implant must be countersunk, it may be placed up to 1.5 mm deeper than the last thread. All one-piece zirconia implants should be surrounded by at least

1.5 mm of bone, with 3 mm of bone between two implants. The implant diameter should be based on the tooth being replaced, anticipated occlusal forces and the available space between the roots of adjacent teeth. The minimum distance of the implant shoulder to the adjacent teeth is 0.5 mm, measured from the greatest curvature of the adjacent teeth, keeping in mind that the implant shoulder can be adjusted up to 1.0 mm when necessary.

Abutment preparation

After insertion of the one-piece implant, it may be necessary to prepare the abutment to meet the anatomical demands of the site. Ideally, all biting forces should be directed along the long axis of the implant, but the abutment aspect of the implant may be prepared to compensate for angulations of up to 25°. If available, wax-ups should be used to aid in treatment planning. When adjusting the abutment immediately after implant placement, red ring, ultra-fine-grain (46 µm) diamond burs should be used to a maximum bur speed of 160,000 rpm. A minimum of 50 ml/min of irrigation should be utilised during the procedure, and excessive forces should be minimised on the newly placed implant.

The abutment should only be prepared enough to allow for adaptation of the provisional restoration, as more definitive adjustments will be made after soft-tissue healing. If the shoulder needs to be lowered in the mesial or distal aspects of the site, this should be completed prior to closure of the soft tissue. As the provisional restoration will need to be out of occlusion, the abutment should be a minimum of 1.5 mm below the plane of occlusion, but no less than 3.0 mm in height. After the healing phase and implant osseointegration, the definitive preparation of the implant shoulder can be completed.

Bone-implant contact

One of the key factors in dental implantology is good primary stability. What we considered in our learning curve is that we increased the bone-implant contact by condensing the spongy bone. Depending on the bone, we drilled with the final drill only through the cortical bone and no longer the spongy bone. By inserting the implant at a higher torque (up to 45–50 Ncm), we compressed the spongy bone with the implant and increased the bone-implant contact in the spongy bone. This technique should only be used for the spongy bone.

Ideal emergence profile

Gingival biotype

The thick and flat gingival biotype offers the best overall aesthetic results, including the best coverage of the margin and papillae preservation. The thin and scalloped biotype makes it more challenging to adjust and maintain the best cervical margin. However, using zirconia implants eliminates the problem of the grey gingival shadow as-

sociated with titanium implants. If recession occurs and exposes the crown margin, although less aesthetically pleasing, it will not be as undesirable as with an exposed titanium surface.

Surface characteristics

In a number of clinical studies, zirconia has been shown to have great tissue biocompatibility and long-term stability. When in contact with tissue fluids, the implant surface carries a neutral polarity, which disables bacterial aggregation. This, in combination with the lack of a micro-gap, makes the one-piece zirconia implant a great tool for managing the soft tissue. These characteristics allow for excellent gingival health and even spontaneous growth of soft tissue, which is an advantage for the long-term aesthetics of dental implants.

Bone and soft-tissue level

Just as with any dental implant, the best aesthetics will be achieved when the implant has good bony support on all four walls. Clearly, this is best accomplished with an atraumatic extraction and ideal placement of the implant, but when this is not possible, bone grafting may be necessary. If a significant amount of marginal bone is lost during extraction or there is a vertical discrepancy in ridge height compared with adjacent teeth, an implant restoration will require a longer crown to compensate. This situation should be avoided in the aesthetic zone, particularly in patients with a high smile line. If a one-wall or small-volume defect is present and immediate implant placement is planned for the patient, bone grafting material may be used, which is well-accepted by zirconia implants. For larger defects where a significant volume of bone is missing, a two-stage procedure should be undertaken and implant placement delayed until completion of grafting.

Implant positioning

The ideal emergence profile of an implant will be created by placing the implant in its ideal position. Selecting the proper implant diameter is a vital part of this process. Implant diameters must be properly matched with

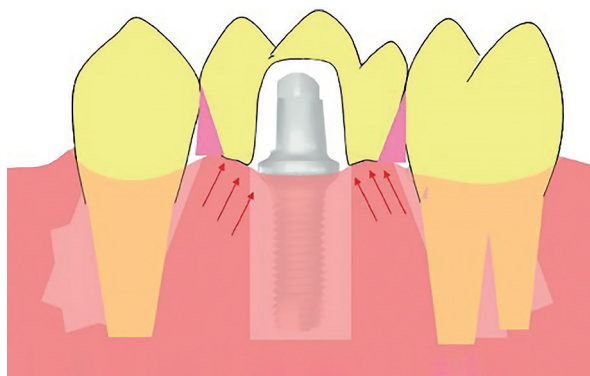


Fig. 5: Illustration of safe 1.5mm distance from one-piece implant to the interior of an egg-shell provisional during healing process.

the size of the interdental space to be restored. Implants must also be placed in their ideal vertical position to achieve proper emergence. For one-piece zirconia implants, there is a range of 1.5mm in vertical positioning for which ideal aesthetics can be maintained. Necessity of countersinking is situation-specific and depends on operator preference, but in general is necessary when the crestal bone is thin or irregular or soft tissue is very thin. Implants can be countersunk so that the implant neck is partially embedded in crestal bone and the shoulder remains subgingival.

Implant preparation

Ideally, implants are prepared after osseointegration and tissue remodelling has been completed. The implant shoulder should be scalloped to match the gingival contour of the tissue and allow for subgingival placement of the crown shoulder. The recommended shoulder design is a chamfer, which can be easily created with a Torpedo ISO 016 bur. The maximum speed of rotary instruments used on zirconia implants is 160,000rpm with copious irrigation. Other important adjustments include angulation of the abutment portion to match adjacent teeth and creating a common path of insertion for multi-unit prostheses. Narrow neck implants, which are designed without a clear marginal line, may require less or even no intraoral adjustments. When necessary, they can be prepared with the Flame ISO 012 bur for a knife-edge-type shoulder design.

Provisionals

Provisionals should be well adapted and polished so as not to irritate the tissue and hinder the healing process (Fig. 5). Since the implant shoulder will be slightly subgingival, so must the provisional be. It should have good circumferential contact with the shoulder and be wide enough to allow the tissue to heal with the proper contour for emergence and to maintain papillary architecture. The operator should consider changing or rebasing the provisional restoration after approximately three weeks of healing to aid in soft-tissue management. After this time, the tissue will be approaching its final conformation, and additional contouring of the provisional will allow for any necessary adjustments to soft-tissue shape. It is extremely important and necessary, to place no provisionals in any occlusal position during the healing process. Patients must understand and be cooperative avoiding the area during the healing process.

Common mistakes

Incorrect implant positioning

One-piece implants demand accuracy in placement owing to the limited ability to compensate for mistakes compared with two-piece implant systems. It is important to plan properly and use advanced planning techniques such as cone-beam computed tomography, digitally

guided implant placement and surgical guides whenever possible. Improper placement can lead to non-restorable implants, apical exposure, proximity to adjacent roots, or unfavourable forces on the restored implant.

Premature loading

Mastication, cheek pressure and tongue pressure can cause implant micro-movements that may lead to failure in the integration process of the implant. In order to adequately protect the implant, there are a variety of provisional restorations that can be employed, including an Essix appliance, eggshell temporary, re-worked denture, Maryland bridge, posterior adhesive bridge or thermoplastic clasp denture. The success of the implant is highly dependent on adequate protection during the integration period. Therefore, a proper protective device should be fabricated within the first 24 hours. The device should provide 1–1.5 mm of free space circumferentially around the abutment and be out of occlusion during all functional and parafunctional movements. After the osseointegration of the implant and final crown placement, the proper adjustment of occlusion of the final restoration is extremely important, also to avoid fractures.

Improper abutment preparation

Poor abutment preparation may lead to discrepancies in spacing or angulation. If the implant is prepared in such a way that one side of the abutment is trimmed much more than the other, the resulting crown may not be balanced over the implant and deleterious forces may be transmitted.

Incorrect implant width

As with conventional dental implants, the mesiodistal width of the site for implant placement should provide at least 1 mm of bone between the implant and adjacent teeth. In order for the one-piece implants to be placed, including the wider shoulder area, the important area to measure is between the height of curvature of the adjacent teeth. There should be a minimum of 0.5 mm on either side of the implant to allow placement. With less than 0.5 mm of space, aesthetics will be compromised and the patient may have difficulty cleaning the area properly. In addition, ingrowth of papillae may be truncated, which would also negatively impact the aesthetic outcome.

Soft-tissue biotype

For one-piece zirconia implants, one important consideration is that implants should be countersunk in those with a thin and scalloped gingival biotype. The implant shoulder should be inserted into the bone as deep as possible to attain a suitable cervical emergence profile. By misjudging or neglecting to consider the gingival biotype, one may end up excessively grinding the implant shoulder to attempt to place the finishing line in a sub-

gingival location. Often the result is an unaesthetic supra-gingival finishing line and poor papillary ingrowth.

Summary

Clinical benefits of one-piece zirconia implant systems are as follows:

1. single-stage procedure;
2. decreased chair time;
3. less-complex armamentarium;
4. elimination of laboratory time for abutment fabrication, and no need for healing abutments, screws, analogues or transfer copings;
5. no internal screws, no internal gaps, no micro-gaps, fewer locations for hardware failures;
6. excellent soft-tissue integration;
7. less consequences from gingival recession;
8. no grey gingival show-through;
9. flexural strength;
10. improved gingival health;
11. force distribution; and
12. no metal parts.

Clinical disadvantages of one-piece zirconia implant systems are the following:

1. implant must be protected during healing;
2. less ability to compensate for incorrect implant angulation;
3. necessity for a good patient compliance; and
4. healing process may last from three to six months, depending on bone quality.

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