Corals as Bone Substitutes

V Manoj Kumar¹, Girish Kumar Govind², B Siva³, Panchami Marish⁴, S Ashwin⁵, Madhu Kiran⁶

Contributors:
¹Professor and Head, Department of OMFS, Mahe Institute of Dental Sciences & Hospital, Mahe, Puducherry, India; ²Professor, Department of OMFS, Mahe Institute of Dental Sciences & Hospital, Mahe, Puducherry, India; ³Reader, Department of Oral Pathology and Microbiology, Mahe Institute of Dental Sciences & Hospital, Mahe, Puducherry, India; ⁴Reader, Department of Oral Medicine and Radiology, Mahe Institute of Dental Sciences & Hospital, Mahe, Puducherry, India; ⁵Senior Lecturer, Department of Orthodontics, Mahe Institute of Dental Sciences & Hospital, Mahe, Puducherry, India; ⁶Reader, Department of Oral Pathology and Radiology, Mahe Institute of Dental Sciences & Hospital, Mahe, Puducherry, India.

Key Words: Alloplastic, bone grafts, calcium carbonate, coral, osteoinductive

Introduction
Bone grafts are necessary for the correction of many oral and maxillo-facial bony defects.¹ A considerable research is presently being conducted to find the ideal material to support bone repair or regeneration.² The deficiencies of autogenous grafts and allogenic banked bone have led to the search for synthetic alloplast alternatives.³ There is now good evidence that synthetic materials can promote bone repair and that both resorbable and nonresorbable alloplastic materials are osteoconductive but have no osteoinductive effect.⁴ Calcium carbonate is now being used as a substitute in periodontal surgery to regenerate lost periodontium, and has recently been used in association with implants.⁵

Natural coral porous calcium carbonate appears to be a clinically useful bone replacement graft material that gives essentially similar or slightly better responses in osseous defects than other bone replacement graft materials. Its other advantages include better clinical handling, resorbability and potential for improved bone regeneration. This material appears to be safe and clinically effective for treating various osseous defects. Its porous structure is similar to that of bone. Coral skeleton, when implanted into bone tissue, is progressively resorbed by osteoclasts, and the osteoblasts use the freed calcium ions, producing new bone, unlike porous hydroxyapatite ceramics which act as a passive matrix for osseous in growth.⁶

The calcium carbonate skeleton of marine corals fulfills all requirements of an ideal bone substitute in a surgical field. The deficiencies of autogenous bone grafts and alloplastic materials are presently being conducted to find the ideal material to support bone repair or regeneration.³ The current study is carried out to evaluate the ease of preparing a potential alloplastic bone substitute and its use of different bone grafting procedures. The current study is carried out to evaluate the ease of preparing a potential alloplastic bone substitute and its use of different bone grafting procedures. The study includes the use of coral graft after cyst enucleation, correction of periodontal bone loss and as onlay graft for orthognathic augmentation, and as interpositional graft in preprosthetic surgery. Their biocompatibility and behavior in these three types of procedures were clinically and radiologically evaluated in intervals of 2-week up to a period of 8 weeks.

Results: In the cases which coral were used for filling bony defects, as granules the results were commendable. Natural coral skeleton, which was used in defects after cyst enucleation, extracted sockets and in periodontal defects showed very good results. There was no loss in the volume of the graft material nor was there any exposure of the graft material. The corals were tolerated well, and the wound healing was uneventful. This shows that natural coral skeleton is a biocompatible bone graft substitute.

Conclusion: The results of our study show that natural coral skeleton is a potential bone graft substitute when used as a bone filler. As an onlay graft where coral was used for chin augmentation, good results were seen.
Corals as bone substitutes ... Kumar VM et al


in orthognathic surgeries. Roux et al., in 1988 had used coral fragments as a bone graft substitute to obliterate bur holes and to repair skull defects and reconstruction of the floor of the anterior cranial fossa. They found that corals grafts were well-tolerated and became partially re-ossified as the calcific skeleton was resorbed.

Pouliquin et al., reported the use of coral as a substitute for bone grafts in posterior spinal fusion of children in scoliosis. Their experience with corals as a bone graft substitute in posterior vertebral surgery was encouraging. Jahn in 1992 carried out a set of animal experiments to determine the feasibility of the use of porous coralline hydroxyapatite for middle ear and mastoid reconstruction.

Papacharalambous and Anastasoff had used natural coral skeleton as onlay graft for contour augmentation of the face. They have coral blocks or granules in a subperiosteal fashion in patients with hemifacial microsomia, maxillary hypoplasia, microgenia, and Treacher Collins syndrome. According to them, coral skeleton is a cheap natural biomaterial with excellent biocompatibility. It can be easily shaped, and it maintained its form over the period observed. Alpaslan et al., in their studies on animals implanted with coral showed new bone formation at each time interval and resorption of coral was observed. Bou-Abbödu Naaman in 1994 showed that the bone formation obtained with natural coral skeleton granules is enhanced when the particles are retained at the site of the defect with a protective mesh.

In 1999, Wolford and Freitas have evaluated the long-term clinical and radiographic results of the use of coralline hydroxyapatite in orthognathic surgery. The use of porous block hydroxyapatite as a bone graft substitute in orthognathic surgery and for facial augmentation showed a high percentage of success and efficacy.

Materials and Methods

The experimental corals were harvested from the Gulf of Mannar, ear Tuticorin, and Mandapam in Tamil Nadu, India. They belong to phylum Coelenterata and Family - Poriteslutea. They are reef-forming with various individual coral animals or polyps, occupying cups or corallites in the massive skeleton. The corals have an organic part, which is the poly pandan inorganic part, the exoskeleton. Polyps living on the surface of the reef build up their exoskeleton underneath by fixing calcium ions from sea water. The exoskeleton consists of 98-99% calcium carbonate and 1-2% amino acids. It is highly porous with 60% void volume. The pores are 100-130 µm in diameter and are interconnected by fenestrations. The number and size of the pores are maximal on the external surface while the core is comparatively dense.

It consists in the removal of the organic material and sterilization of the exoskeleton. The solid core of the exoskeleton is removed. The porous outer layer is prepared for the implant. The coral was immersed in 5% sodium hypochlorite solution for 48 h, to loosen the organic part. The solution is kept in a glass container, and the coral block is gently shaken with a tweezer fora minimum of 2 min, every 12 h. Then coral was immersed in distilled water for 48 h to remove all traces of the sodium hypochlorite solution. The prepared coral then dried in natural sunlight for 48 h, wrapped in a gauze pad to prevent charring and sterilized by autoclaving at 121°C for 30 min. The prepared coral skeleton is cut into blocks or slabs, of varying size and shape to be trimmed and contoured according to need. It was easily re-shaped more precisely during the surgical procedure or mechanically fragmented as granules when required (Figure 1).

Six patients were involved in the study included, 4 male and 2 female. All patients underwent pre-operative evaluation, to rule out any systemic disease and routine investigations were done, for fitness to undergo the surgical procedures. Corals were used in the granular form in 3 patients two after cyst enucleation and one in the periodontal bony defect. Corals were used in block form as onlay graft in the correlation of facial asymmetry, augmentation of chin, and as inter-positional graft for ridge augmentation. The patients were evaluated both clinically and radiographically every 2 weeks for a minimum of 8 weeks and until the coral was replaced by bony completely as evidenced radiologically. The biocompatibility and behavior of the material were also studied.

Patient 1: 29-year-old male with a complaint of pain and swelling in the left upper anterior region for 1 week. The diagnosis was a dentigerous cyst in relation to impacted 23. Surgical removal of impacted maxillary left canine, cyst enucleation, and defect filled with coral granules under local anesthesia.

Procedure done: 2 ml of 2% lignocaine hydrochloride with 1:80,000 adrenaline administered as an infraorbital nerve block on the left side maxilla. Crevicular incision extending from 12 to 24 made with number 15 bard-parker blade. Mucoperiosteal flap raised up to the pyriform aperture on the same side. Using a straight fissure bur, bone removed over and around the prominence of 23 crown. Crown and part of the root exposed (Figure 2a). Using an elevator, the impacted tooth elevated. Cyst enucleation is done. Wound irrigated with saline and made clean. Defect (Figure 2b) was packed with corals made into small granules (Figure 2c). Wound closed with 3.0 black silk. Interrupted sutures are given.

Follow-up results

Immediate post-operative showed the presence of swelling and radiographically coral in situ, a radiolucent line of demarcation between coral implant and bone could be appreciated (Figure 2d and e). At 2 weeks post-operative,
there was no complaint of pain, no edema and the wound healing was normal. Radiologically, resorption of the corals could be appreciated. Radiolucent line of demarcation was present. At 4 weeks, there was no complaint of pain and no edema seen, wound healed and there were radiopacity and radiolucent are seen. At 6 weeks post-operative, there were no complaints and radiolucent line between the graft and wound were absent. By 8 weeks post-operative, wound healed completely and there was no complaint of pain (Figure 2f and g), radio-opacity observed suggestive of a new bone formation.

Patient 2: 16-year-old female with complaint of pain and swelling in the upper anterior region on the right side for 6 months diagnosed as periapical cyst 12 (Figure 3c and d). Cyst enucleation in relation to upper maxillary right central incisor and lateral incisor region under local anesthesia and defect filled with corals.

Figure 1: Coral preparations. (a) Cut slab - outer porous layer for preparation, (b) natural coral exo-skelton before preparation, (c) coral immersed in 5% hypochlorite and distilled water, (d and e) prepared coral cut in to different size and shape.
Operative procedure
About 2 ml of 2% lignocaine hydrochloride with 1:80,000 adrenaline administered as infra-orbital nerve block on both sides. Crevicular incision extending from 14 to 23 region made with No.15 Bard Parkerblade. Vertical release incision made at 23 region. Muco periosteal flap raised. Adherent cyst lining released from the flap. Cyst enucleated in toto. Apicectomy done at 11, 12 and retrograde filling done using light cure material. Wound irrigated with saline and made clean. Wound defect packed with corals made into small granule (Figure 3b). Wound close with 3.0 black silk. Interrupted sutures placed.

Follow-up results (Figure 3)
Immediate post-operative (Figure 3c and d), the hemostasis was achieved, primary closure done observed, radiolucent line of demarcation between the graft and normal bone can be appreciated. No complaints of pain, no edema present. No exposure of graft, mixed radio-opacity and radiolucent areas seen, No clear line of demarcation. At 4 weeks post-operative, there was no complaint of pain, no edema and wound heals. Radiopacities and radiolucent areas were seen. Some areas show resorption and new bone formation. At 6 weeks post-operative, no complaint of pain and no wound dehiscence. Radiolucent area of demarcation absent and radiopacity seen, 8 weeks post-operative, no specific complaints and new bone formation can be appreciated.

Patient 3: 21-year-old female with complaint flattening of right lower part of the face diagnosed as facial asymmetry secondary to temporomandibular joint ankylosis (Figure 4a and b). Augmentation for correction of facial asymmetry, using the coral block as onlay graft, under general anesthesia (GA).

Operative procedure
Sliding genioplasty with augmentation of right body of the mandible with coral onlay grafting (Figure 4). Nasotracheal intubation done and GA administered. Genium exposed through a high labial incision. Horizontal cut made and the osteotomized segment repositioned 4 mm to the right side. Fragment stabilized using wiring using wires. A pocket was made by elevating the buccal mucosa subperiosteally on the right side of the body of the mandible. The prepared coral was made into block, trimmed and kept subperiosteally for augmenting the deficient right mandible body region. Wound closed with 3.0 chromic catgut sutures.

Follow-up results (Figure 4)
Immediate post-operative Figure (4c and d), inflammatory swelling present, symmetry seen. Coral were seen in position. At 2 weeks post-operative, mild complaint of pain but no edema seen. No parasthesia of the mental region. Wound healing was normal. Bulk and symmetry and no migration of the graft. Alternate region of one resorption is seen. At 4 weeks post-operative, no complaint of pain, no edema, reduction in bulk of graft noticed coral in place, alternate region with bone resorption and formation seen. At 6 weeks post-operative, bulk reduced considerably, asymmetry developed, reduced radio-opacity suggesting mild loss of coral material. At 8 weeks post-operative, reduced bulk maintained and reduced graft maintained.

Patient 4: 47-year-old female with complaint of loose lower denture for 6 months diagnosed as alveolar ridge atrophy-mandible (Figure 5c). Mandibular ridge augmentation by horizontal sandwich osteotomy was done.

Operative procedure
Mandibular ridge augmentation by horizontal sandwich osteotomy (Figure 5a and b). Nasotracheal intubation. GA administered. Anterior mucosal flap (lingually based) raised from right to left mental foramen up to alveolar crest. Both mental nerves identified almost on the crest. The periosteal incision on alveolar crest from one mental foramen to the other and periosteal flap raised buccally up to inferior border. Subperiosteal funneling done distal to both mental foramina toward retromolar region. Osteotomy cuts made, superior segment osteotomized and mobilized upward. Interposition grafting is done with coral blocks. Interposition grafting done with 2 circum mandibular wiring (Figure 5d). Two small blocks of graft placed in distal tunnel. Wound closed with 3.0 chromic catgut sutures.

Follow-up results (Figure 5)
Immediate post-operative, Mild pain reported in the submental region. Ecchymosis in the lingual aspect noticed. Orthopantomogram (OPG) shows coral graft with well-defined borders. 2 weeks post-operative, complaint of mild pain and pricking sensation. Wound healing was normal. Graft resorption seen on the left side 4 weeks post-operative, no complaint of pain. Graft resorption seen. Borders are not clear. 6 weeks post-operative, no complaint of pain. Graft exposure
seen on the right buccal sulcus. Graft resorption seen. 8 weeks post-operative, partial loss of graft. No complaint of pain. OPG reveals loss of coral graft from the left and right side symphysis region. Decrease in alveolar height.

Patient 5: 20-year-old male with complaint of protruding upper anterior teeth, diagnosed as maxillary prognathism and retruded chin (Figure 6a). Augmentation genioplasty, using corals, was done under GA.

Operative procedure
Anterior maxillary osteotomy and chin augmentation with onlay grafting. 2% lignocaine hydrochloride infiltrated into the surgical site. High labial incision extending from 34 to 44 region. Mucoperiosteal flap raised, bone exposed. Mental nerve identified and isolated, branches dissected loose from attachments. Periosteum stripped up to inferior border of the mandible. Coral trimmed and shaped and position in the sides. Wound closed in layer with 3.0 chromic catgut suture (Figure 6a).

Follow-up results
Immediate post-operative, edema present, complaint of pain reported (Figure 6b). Coral in situ. 2 weeks post-operative, no complaint of pain, no edema and no mobility of the graft or exposure noticed. Wound healing was normal. No migration of the graft. 4 weeks post-operative, no complaint of pain. Wound healing was good. Chin contour maintained (Figure 6c-e). Resorption was seen in the edges of the coral graft. 6 weeks post-operative, no complaint of pain. No loss of chain contour. No loss of volume of the graft seen. 8 weeks post-operative, no complaint of pain, wound healing good. No loss of contour. Graft volume maintained.

Patient 6: 38-year-old male with a complaint of pain in the right lower posterior region. The diagnosis was infected socket 48 with bony defect distal to 47. Curettage of 48 socket and furcation of 47 (Figure 7a) and packing with corals (Figure 7b) under local anaesthesia.

Operative procedure
2 ml of 2% lignocaine hydrochloride with 1:80,000 adrenaline administered as inferior alveolar nerve block on the right side. The crevicular incision made from 46 with a vertical limb along the external oblique ridge. Mucoperiosteal flap raised on the buccal and lingual side. Granulation tissue curetted from the 48 socket and furcation area of 47. Wound irrigated with betadine and saline. Corals packed in the curetted socket and bifurcation of 47. Margins of the flap freshened on the buccal and lingual side to achieve primary closure. Wound closed with 3.0 chromic catgut. Interrupted sutures are given.

Follow-up results (Figure 7)
Immediate post-operative, edema was present and coral in situ. At 2 weeks post-operative, there was no complaint of pain or edema. Wound healing was normal, no dislodgement of graft seen. At 4 weeks post-operative, no complaint of pain.
Discussion

An ideal bone graft or substitute be a material that is biologically inert, readily available, easily adaptable to the site in terms of shape should and size and replaceable by the host bone. It should be capable of osteoinduction and osteoconduction.

The term osteogenic induction is used to define the process whereby one tissue, or products derived from it, causes a second tissue to differentiate into bone. Such a concept presupposes that chemical substances or physical factors, which are termed osteogenic inductors, are contained in the first tissue and that after entry into or contact with connective tissue cells of the second tissue, then causes those cells to differentiate into osteoblasts.

In osteoinduction, active factors released by components in the graft, and most probably from components of the matrix such as bone morphogenetic protein stimulate sensitive cells in the recipient bed to make the graft, the cells are then induced to begin osteogenic activity.

The process in which vascular tissue invades the graft, bringing it hit the osteoblasts that deposit new bone, has been called creeping substitution and represents osteoconduction. Surviving osteocytes of the graft may produce bone directly themselves (osteogenesis). The graft provides a scaffold that serves as a network on which the new bone is deposited.

The porous calcium carbonate structure resulting from the removal of organic material from the genus pontes coral was used by Chiroff et al., as an implant material. The inter-connecting pores of this material were 140-160 um in diameter. Bone specimens recovered 1 year after surgery revealed complete resorption of the coral skeleton in 75% cases. However, in most cases, less than half of the repair tissue was mineralized bone. The reasoning behind using the coral structure was the assumption that it is more organized than the random porosity produced in synthetic biomaterials.

In this study, we have used natural coral skeleton as a bone in cases of bony defects after cyst enucleation, extraction sockets, in periodontal defects, as onlay graft for correction of facial asymmetry and augmentation of chin, and as inter-positional graft for augmentation.

In the cases which coral were used for filling bony defects, as granules the results were commendable. Natural coral skeleton, which was used in defects after cyst enucleation, extracted sockets and in periodontal defects showed very good results. There was no loss in the volume of the graft material nor was there any exposure of the graft material. The corals were tolerated well, and the wound healing was uneventful. This shows that natural coral skeleton is a biocompatible bone graft substitute.

When coral was used as onlay graft for correction of facial asymmetry in the body region of the mandible, there was gradual loss of volume of the graft material.

Coral onlay, which was used for augmentation of the chin, showed good results. There was no loss of volume of the graft material.

Summary and Conclusion

Corals when compared to other bone graft substitutes, does not need any sophisticated equipment for its preparation. It can easily be prepared and needs no technical skill, i.e. the preparation of natural coral is not a technique sensitive one. In our studies, we have seen that the material is bio-compatible. Successful bone replacement depends on the criteria such as good soft tissue cover, adequate sterilization, and strict asepsis. The material can be contoured easily into various forms and sizes according to the required site. The results of our study show that natural coral skeleton is a potential bone graft substitute when used as a bone filler. As an onlay graft where coral was used for chin augmentation good results were seen but where they were used as onlay graft for correction of facial asymmetry and as interpositional graft for ridge augmentation, the results were not so promising.

References